REMARKS

ON THE

ASTRONOMY OF THE BRAHMINS,

FROM THE

TRANSACTIONS

OF THE

ROYAL SOCIETY OF EDINBURGH.

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REMARKS *on the* ASTRONOMY *of the* BRAHMINS.

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[*Read by the Author, March* 2. 1789.]

I. SINCE the time when Astronomy emerged from the obscurity of ancient fable, nothing is better known than its progress through the different nations of the earth. With the era of NABONASSAR, regular observations began to be made in Chaldea; the earliest which have merited the attention of succeeding ages. The curiosity of the Greeks was, soon after, directed to the same object; and that ingenious people was the first that endeavoured to explain, or connect by theory, the various phenomena of the heavens. This work was supposed to be so fully accomplished in the Syntaxis of PTOLEMY, that his system, without opposition or improvement, continued, for more than five hundred years, to direct the Astronomers of Egypt, Italy and Greece. After the sciences were banished from Alexandria, his writings made their way into the east, where, under the Caliphs of Bagdat, Astronomy was cultivated with diligence and success. The Persian Princes followed the example of those of Bagdat, borrowing besides, from Trebisond, whatever mathematical knowledge was still preserved among the ruins of the Grecian empire. The conquests of GENGIS, and afterwards of TIMOUR, though they retarded, did not stop the progress of Astronomy in the east. The grandsons of these two conquerors were equally renowned for their

their love of ſcience: HULAGU reſtored Aſtronomy in Perſia, and ULUGH-BEIGH, by an effort ſtill more ſingular, eſtabliſhed it in Tartary. In the mean time, having paſſed with the Arabs into Spain, it likewiſe found, in ALPHONSO of Caſtile, both a diſciple and a patron. It was carried, ſoon after, into the north of Europe, where, after exerciſing the genius of COPERNICUS, of KEPLER, and of NEWTON, it has become the moſt perfect of all the ſciences.

2. IN the progreſs which Aſtronomy has thus made, through almoſt all the nations, from the Indus to the Atlantic, there is ſcarce a ſtep which cannot be accurately traced; and it is never difficult to determine what each age, or nation received from another, or what it added to the general ſtock of aſtronomical knowledge. The various ſyſtems, that have prevailed in all theſe countries, are viſibly connected with one another; they are all derived from one original, and would incline us to believe, that the manner in which men begin to obſerve the heavens, and to reaſon about them, is an experiment on the human race, which has been made but once.

IT is, therefore, matter of extreme curioſity to find, beyond the Indus, a ſyſtem of aſtronomical knowledge that appears to make no part of the great body of ſcience, which has traverſed, and enlightened the other countries of the earth; a ſyſtem that is in the hands of men, who follow its rules without underſtanding its principles, and who can give no account of its origin, except that it lays claim to an antiquity far beyond the period, to which, with us, the hiſtory of the heroic ages is ſuppoſed to extend.

3. WE owe our firſt knowledge of this aſtronomy to M. LA LOUBERE, who, returning, in 1687, from an embaſſy to Siam, brought with him an extract from a Siameſe manuſcript, which contained tables, and rules, for calculating the places of the ſun and moon *. The manner in which theſe rules were laid down

* Mem. de l'Acad. des Sciences, tom. 8. p. 281. &c.

down, rendered the principles, on which they were founded, extremely obſcure ; and it required a commentator, as converſant with aſtronomical calculation as the celebrated CASSINI, to explain the meaning of this curious fragment. After that period, two other ſets of aſtronomical tables were ſent to Paris, by the miſſionaries in HINDOSTAN ; but they remained unnoticed, till the return of M. LE GENTIL from India, where he had been to obſerve the tranſit of Venus in 1769. This Academician employed himſelf, during the long ſtay, which his zeal for ſcience induced him to make in that country, in acquiring a knowledge of the Indian aſtronomy. The Brahmins thought they ſaw, in the buſineſs of an Aſtronomer, the marks of a *Caſt*, that had ſome affinity to their own, and began to converſe with M. LE GENTIL, more familiarly than with other ſtrangers. A learned Brahmin of Tirvalore, having made a viſit to the French Aſtronomer, inſtructed him in the methods, which he uſed for calculating eclipſes of the ſun and moon, and communicated to him the tables and rules, that are publiſhed in the Memoirs of the Academy of Sciences, for 1772. Since that time, the ingenious and eloquent author of the Hiſtory of Aſtronomy, has dedicated an entire volume to the explanation, and compariſon of theſe different tables, where he has deduced, from them, many intereſting concluſions *. The ſubject indeed merited his attention ; for the Indian aſtronomy has all the preciſion neceſſary for reſolving the great queſtions, with reſpect to its own origin and antiquity, and is by no means among the number of thoſe imperfect fragments of ancient knowledge, which can lead no farther than conjecture, and which an Aſtronomer would gladly reſign to the learned reſearches of the Antiquary, or the Mythologiſt.

4. IT is from theſe ſources, and chiefly from the elaborate inveſtigations of the laſt mentioned work, that I have ſelected

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* Traité de l'Aſtronomie Indienne et Orientale, par M. BAILLY. Paris, 1787.

the materials of the paper, which I have now the honour to lay before this Society; and it is perhaps neceſſary that I ſhould make ſome apology for preſenting here, what can have ſo little claim to originality. The fact is, that notwithſtanding the moſt profound reſpect, for the learning and abilities of the author of the *Aſtronomie Indienne*, I entered on the ſtudy of that work, not without a portion of the ſcepticiſm, which whatever is new and extraordinary in ſcience ought always to excite, and ſet about verifying the calculations, and examining the reaſonings in it, with the moſt ſcrupulous attention. The reſult was, an entire conviction of the accuracy of the one, and of the ſolidity of the other; and I then fancied, that, in an argument of ſuch variety, I might perhaps do a ſervice to others, by preſenting to them, that particular view of it, which had appeared to me the moſt ſtriking. Such, therefore, is the object of theſe remarks; they are directed to three different points: The firſt is to give a ſhort account of the Indian aſtronomy, ſo far as it is known to us, from the four ſets of tables above mentioned; the ſecond, to ſtate the principal arguments, that can be deduced from theſe tables, with reſpect to their antiquity; and the third, to form ſome eſtimate of the geometrical ſkill, with which this aſtronomical ſyſtem is conſtructed. In the firſt, I have followed M. BAILLY cloſely; in the ſecond, though I have ſometimes taken a different road, I have always come to the ſame concluſion; having aimed at nothing ſo much, as to reduce the reaſoning into a narrow compaſs, and to avoid every argument that is not purely aſtronomical, and independent of all hypotheſis; in the third, I have treated of a queſtion which did not fall within the plan of M. BAILLY's work, but have only entered on it at preſent, leaving to ſome future opportunity, the other diſcuſſions to which it leads.

5. THE aſtronomy of India, as you already perceive, is confined to one branch of the ſcience. It gives no theory, nor even any deſcription of the celeſtial phenomena, but ſatisfies

itſelf

itſelf with the calculation of certain changes in the heavens, particularly of the eclipſes of the ſun and moon, and with the rules and tables by which theſe calculations muſt be performed. The Brahmin, ſeating himſelf on the ground, and arranging his ſhells before him, repeats the enigmatical verſes that are to guide his calculation, and from his little tablets of palm leaves, takes out the numbers that are to be employed in it. He obtains his reſult with wonderful certainty and expedition; but having little knowledge of the principles on which his rules are founded, and no anxiety to be better informed, he is perfectly ſatisfied, if, as it uſually happens, the commencement and duration of the eclipſe anſwer, within a few minutes, to his prediction. Beyond this his aſtronomical enquiries never extend; and his obſervations, when he makes any, go no farther than to determine the meridian line, or the length of the day, at the place where he obſerves.

THE objects, therefore, which this aſtronomy preſents to us, are principally three. 1. Tables and rules for calculating the places of the ſun and moon: 2. Tables and rules for calculating the places of the planets: 3. Rules by which the phaſes of eclipſes are determined. Though it is chiefly to the firſt of theſe that our attention at preſent is to be directed, the two laſt will alſo furniſh us with ſome uſeful obſervations.

6. THE Brahmins, like all other Aſtronomers, have diſtinguiſhed from the reſt of the heavens, that portion of them, through which the ſun, moon and planets continually circulate. They divide this ſpace, which we call the zodiac, into twenty-ſeven equal parts, each marked by a group of ſtars, or a conſtellation*. This diviſion of the zodiac is extremely natural in the infancy of aſtronomical obſervation; becauſe the moon completes her circle among the fixed ſtars, nearly in twenty-ſeven days, and ſo makes an actual diviſion of that circle

into

* Mem. ſur l'Aſtronomie des Indiens, par M. LE GENTIL, Hiſt. de l'Acad des Scien. 1772, II. P. 207. The phraſe which we here tranſlate *conſtellations*, ſignifies *the places of the moon in the twelve ſigns*.

into twenty-ſeven equal parts. The moon too, it muſt be remembered, was, at that time, the only inſtrument, if we may ſay ſo, by which the poſitions of the ſtars on each ſide of her path could be aſcertained; and when her own irregularities were unknown, ſhe was, by the rapidity of her motion eaſtward, well adapted for this purpoſe. It is alſo to the phaſes of the moon, that we are to aſcribe the common diviſion of time into weeks, or portions of ſeven days, which ſeems to have prevailed almoſt over the whole earth *. The days of the week are dedicated by the Brahmins, as by us, to the ſeven planets, and what is truly ſingular, they are arranged preciſely in the ſame order.

7. WITH the conſtellations, that diſtinguiſh the twenty-ſeven equal ſpaces, into which their zodiac is divided, the Aſtronomers of India have connected none of thoſe figures of animals, which are among us, of ſo ancient, and yet ſo arbitrary an original. M. LE GENTIL has given us their names, and configurations †. They are formed, for the moſt part, of ſmall groups of ſtars, ſuch as the Pleiades or the Hyades, thoſe belonging to the ſame conſtellation being all connected by ſtraight lines. The firſt of them, or that which is placed at the beginning of their zodiac, conſiſts of ſix ſtars, extending from the head of Aries to the foot of Andromeda, in our zodiac, and occupying a ſpace of about ten degrees in longitude. Theſe conſtellations are far from including all the ſtars in the zodiac. M. LE GENTIL remarks, that thoſe ſtars ſeem to have been ſelected, which are beſt adapted for marking out, by lines drawn between them, the places of the moon in her progreſs through the heavens. *.

AT the ſame time that the ſtars in the zodiac are thus arranged into twenty-ſeven conſtellations, the ecliptic is divided, as with us, into twelve ſigns of thirty degrees each. This diviſion

* Mem. Acad. des Scien. 1772. II. P. 189.

† Ibid. 209.

vision is purely ideal, and is intended merely for the purpose of calculation. The names and emblems by which these signs are expressed, are nearly the same as with us *; and as there is nothing in the nature of things to have determined this coincidence, it must, like the arrangement of the days of the week, be the result of some ancient and unknown communication.

8. THAT motion by which the fixed stars all appear to move eastward, and continually to increase their distance from the place, that the sun occupies at the vernal equinox, is known to the Brahmins, and enters into the composition of all their tables †. They compute this motion to be at the rate of 54″ a-year; so that their *annus magnus*, or the time in which the fixed stars complete an entire revolution, is 24,000 years. This motion is too quick by somewhat less than 4″ a-year; an error that will not be thought great, when it is considered, that PTOLEMY committed one of 14″, in determining the same quantity.

ANOTHER circumstance, which is common to all the tables, and, at the same time, peculiar to the Indian astronomy, is, that they express the longitude of the sun and moon, by their distance from the beginning of the moveable zodiac, and not, as is usual with us, by their distance from the point of the vernal equinox. The longitude is reckoned in signs of 30°, as already mentioned, and each degree is subdivided into 60′, &c. In the division of time, their arithmetic is purely sexagesimal: They divide the day into 60 hours, the hour into 60 minutes, &c.; so that their hour is 24 of our minutes, their minute 24 of our seconds, and so on.

9. THESE

* Mem. Acad. des Scien. 1772. II. P. 200. The zodiac they call *sodi mandalam*, or the circle of stars.

† Ibid. 194. Ast. Indienne, p. 43, &c.

9. THESE remarks refer equally to all the tables. We are now to take notice of what is peculiar to each, beginning with those of Siam.

IN order to calculate for a given time, the place of any of the celestial bodies, three things are requisite. The first is, the position of the body in some past instant of time, ascertained by observation; and this instant, from which every calculation must set out, is usually called the *epoch* of the tables. The second requisite is, the mean rate of the planet's motion, by which is computed the arch in the heavens, that it must have described, in the interval between the epoch and the instant for which the calculation is made. By the addition of this, to the place at the epoch, we find the mean place of the planet, or the point it would have occupied in the heavens, had its motion been subject to no irregularity. The third is, the correction, on account of such irregularity, which must be added to the mean place, or subtracted from it, as circumstances require, in order to have the true place. The correction thus made is, in the language of astronomy, called an equation; and, when it arises from the eccentricity of a planet's orbit, it is called the equation of the centre.

10. THE epoch of the tables of Siam does not go back to any very remote period. M. CASSINI, by an ingenious analysis of their rules, finds that it corresponds to the 21st of March, in the year 638 of our era, at 3 in the morning, on the meridian of Siam *. This was the instant at which the astronomical year began, and at which both the sun and moon entered the moveable zodiac. Indeed, it is to be observed, that, in all the tables, the astronomical year begins when the sun enters the moveable zodiac, so that the beginning of this year is continually advancing with respect to the seasons, and makes the complete round of them in 24,000 years.

FROM

* Mem. Acad. Scien. tom. 8. p. 312. Ast. Indienne, p. 11. § 14.

FROM the epoch above mentioned, the mean place of the ſun for any other time is deduced, on the ſuppoſition that in 800 years, there are contained 292,207 days *. This ſuppoſition involves in it the length of the ſydereal year, or the time that the ſun takes to return to the beginning of the moveable zodiac, and makes it conſiſt of 365 *d.* 6 *h.* 12′, 36″ †. From this, in order to find the tropical year, or that which regulates the ſeaſons, we muſt take away 21′, 55″, as the time which the ſun takes to move over the 54″, that the ſtars are ſuppoſed to have advanced in the year; there will remain 365 *d.* 5 *h.* 50′, 41″, which is the length of the tropical year that is involved, not only in the tables of Siam, but likewiſe, very nearly, in all the reſt ‡. This determination of the length of the year is but 1′, 53″, greater than that of DE LA CAILLE, which is a degree of accuracy beyond what is to be found in the more ancient tables of our aſtronomy.

II. THE next thing with which theſe tables preſent us, is a correction of the ſun's mean place, which correſponds to what we call the equation of his centre, or the inequality ariſing from the eccentricity of his orbit, in conſequence of which, he is alternately retarded and accelerated, his true place being, for one half of the year, left behind the mean, and, for the other, advanced before it. The point where the ſun is placed, when his motion is ſloweſt, we call his apogee, becauſe his diſtance from the earth is then greateſt; but the Indian aſtronomy, which is ſilent with reſpect to theory, treats this point as nothing more than what it appears to be, a point, *viz.* in the heavens, where the ſun's motion is the ſloweſt poſſible, and about 90° diſtant from that, where his greateſt inequality takes place. This greateſt inequality is here made to be

* Aſt. Ind. p. 7. § 6.

† Mem. Acad. Scien. tom. 8. p. 328.

‡ Aſt. Ind. p. 124. The tables of Tirvalore make the year 6″ leſs.

be 2°, 12′ *, about 16′ greater than it is determined, by the modern aſtronomy of Europe. This difference is very conſiderable; but we ſhall find that it is not to be aſcribed wholly to error, and that there was a time when the inequality in queſtion was nearly of the magnitude here aſſigned to it. In the other points of the ſun's path, this inequality is diminiſhed, in proportion to the ſine of the mean diſtance from the apogee, that is, nearly as in our own tables. The apogee is ſuppoſed to be 80° advanced beyond the beginning of the zodiac, and to retain always the ſame poſition among the fixed ſtars, or to move forward at the ſame rate with them †. Though this ſuppoſition is not accurate, as the apogee gains upon the ſtars about 10″ annually, it is much nearer the truth than the ſyſtem of PTOLEMY, where the ſun's apogee is ſuppoſed abſolutely at reſt, ſo as continually to fall back among the fixed ſtars, by the whole quantity of the preceſſion of the equinoxes ‡.

12. IN theſe tables, the motions of the moon are deduced, by certain intercalations, from a period of nineteen years, in which ſhe makes nearly 235 revolutions; and it is curious to find at Siam, the knowledge of that cycle, of which the invention was thought to do ſo much honour to the Athenian Aſtronomer METON, and which makes ſo great a figure in our modern

* THE equation of the ſun, or what they call the *chaiaa*, is calculated in the Siameſe tables only for every 15° of the *matteiomme*, or mean anomaly. CASSINI, *ubi ſupra*, p. 299.

† Aſt. Ind. p. 9.

‡ THE error, however, with reſpect to the apogee, is leſs than it appears to be; for the motion of the Indian zodiac, being nearly 4′ ſwifter than the ſtars, is but 6″ ſlower than the apogee. The velocity of the Indian zodiac is indeed neither the ſame with that of the ſtars, nor of the ſun's apogee, but nearly a mean between them.

modern kalendars *. The moon's apogee is supposed to have been in the beginning of the moveable zodiac, 621 days after the epoch of the 21st of March 638, and to make an entire revolution in the heavens in the space of 3232 days †. The first of these suppositions agrees with MAYER's tables to less than a degree, and the second differs from them only by 11^h, $14'$, $31''$; and if it be considered that the apogee is an ideal point in the heavens, which even the eyes of an astronomer cannot directly perceive, to have discovered its true motion, so nearly, argues no small correctness of observation.

13. FROM the place of the apogee, thus found, the inequalities of the moon's motion, which are to reduce her mean to her true place, are next to be determined. Now, at the oppositions and conjunctions, the two greatest of the moon's inequalities, the equation of the centre and the evection, both depend on the distance from the apogee, and therefore appear but as one inequality. They also, partly, destroy one another; so that the moon is retarded or accelerated, only by their difference, which, when greatest, is, according to MAYER's tables, $4°$, $57'$, $42''$. The Siamese rules, which calculate only for oppositions and conjunctions, give, accordingly, but one inequality to the moon, and make it, when greatest, $4°$, $56'$, not $2'$ less than the preceding. This greatest equation is applied, when the moon's mean distance from the apogee is $90°$; in other situations, the equation is less, in proportion as the sine of that distance diminishes ‡.

14. THE Siamese MS. breaks off here, and does not inform us how the astronomers of that country proceed, in the remaining parts of their calculation, which they seem to have undertaken,

* THE Indian period is more exact than that of our golden number, by 35'. Ast. Ind. p. 5. The Indians regulate their festivals by this period. *Ibid.* Disc. Prelim. p. viii.

† Ast. Ind. p. 11. & 20.

‡ Ast. Indienne, p. 13. CASSINI Mem. Acad. tom. 8. p. 304.

undertaken, merely for ſome purpoſe in aſtrology. M. CASSINI, to whom we are indebted for the explanation of theſe tables, obſerves, that they are not originally conſtructed for the meridian of Siam, becauſe the rules direct to take away 3′ for the ſun, and 40′ for the moon, (being the motion of each for 1^h, 13′), from their longitudes calculated as above *. The meridian of the tables is therefore 1^h, 13′, or 18°, 15′, weſt of Siam; and it is remarkable, that this brings us very near to the meridian of Benares, the ancient ſeat of Indian learning †. The ſame agrees nearly with what the Hindoos call their firſt meridian, which paſſes through Ceylon and the Banks of Ramanancor. We are, therefore, authoriſed, or rather, we are neceſſarily determined to conclude, that the tables of Siam came originally from HINDOSTAN.

15. ANOTHER ſet of aſtronomical tables, now in the poſſeſſion of the Academy of Sciences, was ſent to the late M. DE L'ISLE from Chriſnabouram, a town in the Carnatic, by Father DU CHAMP, about the year 1750. Though theſe tables have an obvious affinity to what have already been deſcribed, they form a much more regular and extenſive ſyſtem of aſtronomical knowledge. They are fifteen in number; and include, beſide the mean motions of the ſun, moon and planets, the equations to the centre of the ſun and moon, and two corrections for each of the planets, the one of which correſponds to its apparent, and the other to its real inequality. They are accompanied alſo with precepts, and examples, which Father DU CHAMP received from the Brahmins of Chriſnabouram, and which he has tranſlated into French ‡.

THE

* Mem. Acad. Scien. tom. 8. p. 302. & 309.

† Aſt. Ind. p. 12. It brings us to a meridian 82°, 34′, eaſt of Greenwich. Benares is 83°, 11′, eaſt of the ſame, by RENNEL's map.

‡ Theſe tables are publiſhed by M. BAILLY, Aſt. Ind. p. 335, &c. See alſo p. 31, &c.

THE epoch of theſe tables is leſs ancient than that of the former, and anſwers to the 10th of March at ſunriſe, in the year 1491 of our era, when the ſun was juſt entering the moveable zodiac, and was in conjunction with the moon; two circumſtances, by which almoſt all the Indian eras are diſtinguiſhed. The places, which they aſſign, at that time, to the ſun and moon, agree very well with the calculations made from the tables of MAYER, and DE LA CAILLE. In their mean motions, they indeed differ ſomewhat from them; but as they do ſo equally for the ſun and moon, they produce no error, in determining the relative poſition of theſe bodies, nor, of conſequence, in calculating the phenomena of eclipſes. The ſun's apogee is here ſuppoſed to have a motion ſwifter than that of the fixed ſtars, by about 1″ in nine years, which, though it falls greatly ſhort of the truth, does credit to this aſtronomy, and is a ſtrong mark of originality. The equation of the ſun's centre is ſomewhat leſs here than in the tables of Siam; it is 2°, 10′, 30″; the equation of the moon's centre is 5°, 2′, 47″; her path, where it interſects that of the ſun, is ſuppoſed to make an angle with it of 4°, 30′, and the motions, both of the apogee and node, are determined very near to the truth.

16. ANOTHER ſet of tables, ſent from India by Father PATOUILLET, were received by M. DE L'ISLE, about the ſame time with thoſe of Chriſnabouram. They have not the name of any particular place affixed to them; but, as they contain a rule for determining the length of the day, which anſwers to the latitude of 16°, 16′, M. BAILLY thinks it probable that they come from Narſapour *.

THE precepts and examples, which accompany theſe tables, though without any immediate reference to them, are confined to the calculation of the eclipſes of the ſun and moon; but the tables themſelves extend to the motion of the planets, and very much reſemble thoſe of Chriſnabouram, except that they are given with leſs detail, and in a form much more

* Aſt. Ind. p. 49, &c.

more enigmatical *. The epoch of the precepts, which M. BAILLY has evolved with great ingenuity, goes back no farther than the year 1569, at midnight, between the 17th and 18th of March. From this epoch, the places of the sun and moon are computed, as in the tables of Siam, with the addition of an equation, which is indeed extremely singular. It resembles that correction of the moon's motion, which was discovered by TYCHO, and which is called the annual equation, because its quantity depends, not on the place of the moon, but on the place of the sun, in the ecliptic. It is every where proportional to the inequality of the sun's motion, and is nearly a tenth part of it. The tables of Narsapour make their annual equation only $\frac{1}{27}$ of the sun's: but this is not their only mistake; for they direct the equation to be added to the moon's longitude, when it ought to be subtracted from it, and *vice versa*. Now, it is difficult to conceive from whence the last mentioned error has arisen; for though it is not at all extraordinary, that the astronomers, who constructed these tables, should mistake the quantity of a small equation, yet it is impossible, that the same observations, which informed them of its existence, should not have determined, whether it was to be added or subtracted. It would seem, therefore, that something accidental must have occasioned this error; but however that be, an inequality in the lunar motions, that is found in no system with which the astronomers of India can have had any communication, is at least a proof of the originality of their tables.

17. THE tables, and methods, of the Brahmins of Tirvalore, are, in many respects, more singular than any that have yet been

* THEY were explained, or rather decyphered by M. LE GENTIL in the Memoirs of the Academy of Sciences for 1784, p. 482, &c.; for they were not understood by the missionary who sent them to Europe, nor probably by the Brahmins who instructed him. M. LE GENTIL thinks that they have the appearance of being copied from inscriptions on stone. The minutes and seconds are ranged in rows under one another, not in vertical columns, and without any title to point out their meaning, or their connection. These tables are published, Mem. Acad. *ibid.* p. 492, and Ast. Ind. p. 414.

been deſcribed *. The ſolar year is divided, according to them, into twelve unequal months, each of which is the time that the ſun takes to move through one ſign, or 30°, of the ecliptic. Thus, *Any*, or June, when the ſun is in the third ſign, and his motion ſloweſt, conſiſts of 31^d, 36^h, 38′, and *Margagy*, or December, when he is in the ninth ſign, and his motion quickeſt, conſiſts only of 29^d, 20^h, 53′ †. The lengths of theſe months, expreſſed in natural days, are contained in a table, which, therefore, involves in it the place of the ſun's apogee, and the equation of his centre. The former ſeems to be 77° from the beginning of the zodiac, and the latter about 2°, 10′, nearly as in the preceding tables. In their calculations, they alſo employ an aſtronomical day, which is different from the natural, being the time that the ſun takes to move over one degree of the ecliptic; and of which days there are juſt 360 in a year ‡.

18. These tables go far back into antiquity. Their epoch coincides with the famous era of the Calyougham, that is, with the beginning of the year 3102 before Christ. When the Brahmins of Tirvalore would calculate the place of the ſun for a given time, they begin by reducing into days the interval between that time, and the commencement of the Calyougham, multiplying the years by 365^d, 6^h, 12′, 30″; and taking away 2^d, 3^h, 32′, 30″, the aſtronomical epoch having begun that much later than the civil ‖. They next find, by means of certain diviſions, when the year current began,

* Tirvalore is a ſmall town on the Coromandel coaſt, about 12 G. miles weſt of Negapatnam, in Lat. 10°, 44′, and eaſt Long. from Greenwich, 79°, 42′, by Rennel's map. From the obſervations of the Brahmins, M. le Gentil makes its Lat. to be 10°, 42′, 13′. (Mem. Acad. Scien. II. P. 184.) The meridian of Tirvalore nearly touches the weſt ſide of Ceylon, and therefore may be ſuppoſed to coincide with the firſt meridian, as laid down by Father du Champ. There is no reduction of Longitude employed in the methods of Tirvalore.

† Theſe are Indian hours, &c.

‡ Mem. Acad. des Scien. II. P. 187. Aſt. Indienne, p. 76, &c.

‖ The Indian hours are here reduced to European.

gan, or how many days have elapſed ſince the beginning of it, and then, by the table of the duration of months, they reduce theſe days into aſtronomical months, days, *&c.* which is the ſame with the ſigns, degrees and minutes of the ſun's longitude from the beginning of the zodiac. The ſun's longitude, therefore, is found.

19. SOMEWHAT in the ſame manner, but by a rule ſtill more artificial and ingenious, they deduce the place of the moon, at any given time, from her place at the beginning of the Calyougham *. This rule is ſo contrived, as to include at once the motions both of the moon and of her apogee, and depends on this principle, according to the very ſkilful interpretation of M. BAILLY, that, 1,600,894 days after the above mentioned epoch, the moon was in her apogee, and 7^s, $2°$, $0'$, $7''$, diſtant from the beginning of the zodiac; that after 12,372 days, the moon was again in her apogee, with her longitude increaſed, 9^s, $27°$, $48'$, $10''$; that in 3031 days more, the moon is again in her apogee, with 11^s, $7°$, $31'$, $1''$, more of longitude; and, laſtly, that, after 248 days, ſhe is again in her apogee, with $27°$, $44'$, $6''$, more of longitude. By means of the three former numbers, they find, how far, at any given time, the moon is advanced in this period of 248 days, and by a table, expreſſing how long the moon takes to paſs through each degree of her orbit, during that period, they find how far ſhe is then advanced in the zodiac †. This rule is ſtrongly marked with all the peculiar characters of the Indian aſtronomy: It is remarkable for its accuracy, and ſtill more for its ingenuity and refinement; but is not reduced withal, to its ultimate ſimplicity.

20. THE tables of Tirvalore, however, though they differ in form very much from thoſe formerly deſcribed, agree with them

* Mem. Acad. des Scien. *ibid.* p. 229. Aſt. Ind. p. 84.

† M. LE GENTIL has given this table, Mem. Acad. *ibid.* p. 261.

them perfectly in many of their elements. They ſuppoſe the ſame length of the year, the ſame mean motions, and the ſame inequalities of the ſun and moon, and they are adapted nearly to the ſame meridian *. But a circumſtance in which they ſeem to differ materially from the reſt is, the antiquity of the epoch from which they take their date, the year 3102 before the Chriſtian era. We muſt, therefore, enquire, whether this epoch is real or fictitious, that is, whether it has been determined by actual obſervation, or has been calculated from the modern epochs of the other tables. For it may naturally be ſuppoſed, that the Brahmins, having made obſervations in later times, or having borrowed from the aſtronomical knowledge of other nations, have imagined to themſelves a fictitious epoch, coinciciding with the celebrated era of the Calyougham, to which, through

* THE accuracy of the geography of the Hindoos, is in no proportion to that of their aſtronomy, and, therefore, it is impoſſible that the identity of the meridians of their tables can be fully eſtabliſhed. All that can be ſaid, with certainty, is, that the difference between the meridians of the tables of Tirvalore and Siam is, at moſt, but inconſiderable, and may be only apparent, ariſing from an error in computing the difference of longitude between theſe places. The tables of Tirvalore are for Long. 79°, 42′; thoſe of Siam for 82°, 34′; the difference is 2°, 52′, not more than may be aſcribed to an error purely geographical.

As to the tables of Chriſnabouram, they contain a reduction, by which it appears, that the place where they are now uſed is 45′ of a degree eaſt of the meridian for which they were originally conſtructed. This makes the latter meridian agree tolerably with that of Cape Comorin, which is in Long. 77°, 32′, 30″, and about half a degree weſt of Chriſnabouram. But this concluſion is uncertain; becauſe, as M. BAILLY has remarked, the tables ſent from Chriſnabouram, and underſtood by Father DU CHAMP to belong to that place, are not adapted to the latitude of it, but to one conſiderably greater, as appears from their rule for aſcertaining the length of the day. (Aſt. Ind. p. 33.)

THE characters, too, by which the Brahmins diſtinguiſh their firſt meridian, are not perfectly conſiſtent with one another. Sometimes it is deſcribed as biſecting Ceylon; and at other times, as touching it on the weſt ſide, or even as being as far weſt as Cape Comorin. Lanka, which is ſaid to be a point in it, is underſtood, by Fath. DU CHAMP. to be Ceylon. M. BAILLY thinks that it is the lake Lanka, the ſource of the Gogra, placed by M. RENNEL, as well as the middle of Ceylon, in Long. 80°, 42′; but, from a Hindoo map, in the Ayeen Akbery, vol. iii. p. 25. Lanka appears to be an iſland which marks the interſection of the firſt meridian of the map, nearly that of Cape Comorin, with the equator; and is probably one of the Maldivy iſlands. See alſo a note in the Ayeen Akbery, *ibid.* p. 36.

through vanity or ſuperſtition, they have referred the places of the heavenly bodies, and have only calculated what they pretend that their anceſtors obſerved.

21. In doing this, however, the Brahmins muſt have furniſhed us with means, almoſt infallible, of detecting their impoſture. It is only for aſtronomy, in its moſt perfect ſtate, to go back to the diſtance of forty-ſix centuries, and to aſcertain the ſituation of the heavenly bodies at ſo remote a period. The modern aſtronomy of Europe, with all the accuracy that it derives from the teleſcope and the pendulum, could not venture on ſo difficult a taſk, were it not aſſiſted by the theory of gravitation, and had not the integral calculus, after an hundred years of almoſt continual improvement, been able, at laſt, to determine the diſturbances in our ſyſtem, which ariſe from the action of the planets on one another.

Unless the corrections for theſe diſturbances be taken into account, any ſyſtem of aſtronomical tables, however accurate at the time of its formation, and however diligently copied from the heavens, will be found leſs exact for every inſtant, either before or after that time, and will continually diverge more and more from the truth, both for future and paſt ages. Indeed, this will happen, not only from the neglect of theſe corrections, but alſo from the ſmall errors unavoidably committed, in determining the mean motions, which muſt accumulate with the time, and produce an effect that becomes every day more ſenſible, as we retire, on either ſide, from the inſtant of obſervation. For both theſe reaſons, it may be eſtabliſhed as a maxim, that, if there be given a ſyſtem of aſtronomical tables, founded on obſervations of an unknown date, that date may be found, by taking the time when the tables repreſent the celeſtial motions moſt exactly.

Here, therefore, we have a criterion, by which we are to judge of the pretenſions of the Indian aſtronomy to ſo great antiquity. It is true, that, in applying it, we muſt ſuppoſe our modern

modern aſtronomy, if not perfectly accurate, at leaſt ſo exact as to repreſent the celeſtial motions, without any ſenſible error, even for a period more remote than the Calyougham; and this, conſidering the multitude of obſervations on which our aſtronomy is founded, the great antiquity of ſome of thoſe obſervations, and the extreme accuracy of the reſt, together with the aſſiſtance derived from the theory of phyſical cauſes, may ſurely be aſſumed as a very reaſonable poſtulatum. We begin with the examination of the mean motions.

22. THE Brahmins place the beginning of their moveable zodiac, at the time of their epoch, 54° before the vernal equinox, or in the longitude of 10^s, 6°, according to our method of reckoning. Now, M. LE GENTIL brought with him a delineation of the Indian zodiac, from which the places of the ſtars in it may be aſcertained with tolerable exactneſs *. In particular, it appears, that Aldebaran, or the firſt ſtar of Taurus, is placed in the laſt degree of the fourth conſtellation, or 53°, 20′, diſtant from the beginning of the zodiac. Aldebaran was therefore 40′ before the point of the vernal equinox, according to the Indian aſtronomy, in the year 3102 before CHRIST. But the ſame ſtar, by the beſt modern obſervations, was, in the year 1750, in longitude, 2^s, 6°, 17′, 47″; and had it gone forward, according to the preſent rate of the preceſſion of the equinoxes, 50″$\frac{1}{3}$ annually, it muſt have been, at the era of the Calyougham, 1°, 32′, before the equinox. But this reſult is to be corrected, in conſequence of the inequality in the preceſſion, diſcovered by M. DE LA GRANGE †, by the addition of 1°, 45′, 22″, to the longitude of Aldebaran, which gives the longitude of that ſtar 13′ from the vernal equinox, at the time of the Calyougham, agreeing, within 53′, with the determination of the Indian aſtronomy ‡.

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* Mem. Acad. Scien. 1772, II. P. 214. Aſt. Ind. p. 129.

† Mem. Acad. de Berlin, 1782, p. 287. Aſt. Ind. p. 144.

‡ Aſt. Ind. p. 130.

THIS agreement is the more remarkable, that the Brahmins, by their own rules for computing the motion of the fixed ſtars, could not have aſſigned this place to Aldebaran for the beginning of the Calyougham, had they calculated it from a modern obſervation. For as they make the motion of the fixed ſtars too great by more than 3″ annually, if they had calculated backward from 1491, they would have placed the fixed ſtars leſs advanced by 4° or 5°, at their ancient epoch, than they have actually done. This argument carries with it a great deal of force; and even were it the only one we had to produce, it would render it, in a high degree, probable, that the Indian zodiac was as old as the Calyougham.

23. LET us next compare the places of the ſun and moon, for the beginning of the Calyougham, as deduced from the Indian and the modern aſtronomy. And, firſt, of the ſun, though, for a reaſon that will immediately appear, it is not to be conſidered as leading to any thing concluſive. M. BAILLY, from a compariſon of the tables of Tirvalore with thoſe of Chriſnabouram, has determined the epoch of the former to anſwer to midnight, between the 17th and 18th * of February of the year 3102 before CHRIST, at which time the ſun was juſt entering the moveable zodiac, and was therefore in longitude 10ˢ, 6°. M. BAILLY alſo thinks it reaſonable to ſuppoſe, that this was not the mean place of the ſun, as the nature of aſtronomical tables require, but the true place, differing from the mean, by the equation to the ſun's centre at that time †. This, it muſt be confeſſed, is the mark of greateſt unſkilfulneſs, that we meet with in the conſtruction of theſe tables. Suppoſing it, however, to be the caſe, the mean place of the ſun, at the time of

* Aſt. Ind. p. 110. The Brahmins, however, actually ſuppoſe the epoch to be 6 hours later, or at ſunriſe, on the ſame day. Their miſtake is diſcovered, as has been ſaid, by comparing the radical places in the different tables with one another.

† Aſt. Ind. p. 83.

of the epoch, comes out 10^s, 3°, $38'$, $13''$. Now, the mean longitude of the sun, from DE LA CAILLE's tables, for the same time, is 10^s, 1°, $5'$, $57''$, supposing the precession of the equinoxes to have been uniformly at the rate it is now, that is, $50''\frac{1}{3}$ annually. But M. DE LA GRANGE has demonstrated, that the precession was less in former ages than in the present; and his formula gives 1°, $45'$, $22''$, to be added, on that account, to the sun's longitude already found, which makes it 10^s, 2°, $51'$, $19''$, not more than $47'$ from the radical place in the tables of Tirvalore. This agreement is near enough to afford a strong proof of the reality of the ancient epoch, if it were not for the difficulty that remains about considering the sun's place as the true, rather than the mean; and, for that reason, I am unwilling that any stress should be laid upon this argument. The place of the moon is not liable to the same objection.

24. THE moon's mean place, for the beginning of the Calyougham, (that is, for midnight between the 17th and 18th of February 3102, A. C. at Benares), calculated from MAYER's tables, on the supposition that her motion has always been at the same rate as at the beginning of the present century, is 10^s, 0°, $51'$, $16''$ *. But, according to the same astronomer, the moon is subject to a small, but uniform acceleration, such, that her angular motion, in any one age, is $9''$ greater than in the preceding, which, in an interval of 4801 years, must have amounted to 5°, $45'$, $44''$. This must be added to the preceding, to give the real mean place of the moon, at the astronomical epoch of the Calyougham, which is therefore 10^s, 6°, $37'$. Now, the same, by the tables of Tirvalore, is 10^s, 6°, $0'$; the difference is less than two-thirds of a degree, which, for so remote a period, and considering the acceleration of the moon's motion, for which no allowance could

* Ast. Ind. p. 142, &c. The first meridian is supposed to pass through Benares; but even if it be supposed 3° farther west, the difference, which is here 37′, will be only increased to 42′.

could be made in an Indian calculation, is a degree of accuracy that nothing but actual obfervation could have produced.

25. To confirm this conclufion, M. BAILLY computes the place of the moon for the fame epoch, by all the tables to which the Indian aftronomers can be fuppofed to have ever had accefs *. He begins with the tables of PTOLEMY; and if, by help of them, we go back from the era of NABONASSAR, to the epoch of the Calyougham, taking into account the comparative length of the Egyptian and Indian years, together with the difference of meridians between Alexandria and Tirvalore, we fhall find the longitude of the fun 10°, 21′, 15″ greater, and that of the moon 11°, 52′, 7″ greater than has juft been found from the Indian tables †. At the fame time that this fhews, how difficult it is to go back, even for a lefs period than that of 3000 years, in an aftronomical computation, it affords a proof, altogether demonftrative, that the Indian aftronomy is not derived from that of PTOLEMY.

THE tables of ULUGH BEIG are more accurate than thofe of the Egyptian aftronomer. They were conftructed in a country not far from India, and but a few years earlier than 1491, the epoch of the tables of Chrifnabouram. Their date is July 4. at noon, 1437, at Samarcand; and yet they do not agree with the Indian tables, even at the above mentioned epoch of 1491 ‡. But, for the year 3102 before CHRIST, their difference from them, in the place of the fun, is 1°, 30′, and in that of the moon 6°; which, though much lefs than the former differences, are fufficient to fhow, that the tables of India are not borrowed from thofe of Tartary.

THE Arabians employed in their tables the mean motions of PTOLEMY; the Perfians did the fame, both in the more ancient tables of CHRYSOCOCCA, and the later ones of NASSIREDDIN ‖. It is

* Aft. Ind. p. 114.

† Ibid. p. 115.

‡ Ibid. p. 117.

‖ Ibid. p. 118.

is therefore certain, that the aſtronomy of the Brahmins is neither derived from that of the Greeks, the Arabians, the Perſians or the Tartars. This appeared ſo clear to CASSINI, though he had only examined the tables of Siam, and knew nothing of many of the great points which diſtinguiſh the Indian aſtronomy from that of all other nations, that he gives it as his opinion, that theſe tables are neither derived from the Perſian aſtronomy of CHRYSOCOCCA, nor from the Greek aſtronomy of PTOLEMY; the places they give at their epoch to the apogee of the ſun, and of the moon, and their equation for the ſun's centre, being very different from both *.

26. BUT, to return to what reſpects the moon's acceleration; it is plain, that tables, as ancient as thoſe of Tirvalore pretend to be, ought to make the mean motion of that planet much ſlower than it is at preſent. They do accordingly ſuppoſe, in the rule for computing the place of the moon, already deſcribed, that her motion for 4383 years, 94 days, reckoned in the moveable zodiac from the epoch of the Calyougham, is 7^s, $2°$, $0'$, $7''$, or 9^s, $7°$, $45'$, $1''$, when referred to the fixed point of the vernal equinox. Now, the mean motion for the ſame interval, taken from the tables of MAYER, is greater than this, by $2°$, $42'$, $4''$ †, which, though conformable, in general, to the notion of the moon's motion having been accelerated, falls, it muſt be confeſſed, greatly ſhort of the quantity which MAYER has aſſigned to that acceleration. This, however, is not true of all the tables; for the moon's motion in 4383 years, 94 days, taken from thoſe of Chriſnabouram, is $3°$, $2'$, $10''$ leſs than in the tables of Tirvalore ‡; from which it is reaſonable to conclude, with M. BAILLY, that the former are, in reality, more ancient than the latter, though they do not profeſs to be ſo: and hence, alſo, the tables of Chriſnabouram make

* Mem. Acad. Scien. tom. 8. p. 286.

† Aſt. Ind. p. 145.

‡ Ibid. p. 126.

make the moon's motion leſs than MAYER's, for the above mentioned interval, by 5°, 44′, 14″, which therefore is, according to them, the quantity of the acceleration.

27. Now, it is worthy of remark, that if the ſame be computed on MAYER's principles, that is, if we calculate how much the angular motion of the moon for 4383 years, 94 days, dated from the beginning of the Calyougham, muſt have been leſs than if her velocity had been all that time uniform, and the ſame as in the preſent century, we ſhall find it to be 5°, 43′, 7″, an arch which is only 1′, 7″, leſs than the former. The tables of Chriſnabouram, therefore, agree with thoſe of MAYER, when corrected by the acceleration within 1′, 7″, and that for a period of more than four thouſand years. From this remarkable coincidence, we may conclude, with the higheſt probability, that at leaſt one ſet of the obſervations, on which thoſe tables are founded, is not leſs ancient than the Calyougham; and though the poſſibility of their being ſome ages later than that epoch, is not abſolutely excluded, yet it may, by ſtrict mathematical reaſoning, be inferred, that they cannot have been later than 2000 years before the Chriſtian era *.

28. THIS

* THE reaſoning here referred to is the following: As the mean motions, in all aſtronomical tables, are determined by the compariſon of obſervations made at a great diſtance of time from one another; if x be the number of centuries between the beginning of the preſent, and the date of the more ancient obſervations, from which the moon's mean motion in the tables of Chriſnabouram is deduced; and if y denote the ſame for the more modern obſervations: then the quantity by which the moon's motion, during the interval $x-y$, falls ſhort of MAYER's, for the ſame interval, is $(x^2-y^2)9''$.

IF, therefore, m be the motion of the moon for a century in the laſt mentioned tables, $m(x-y)-9''(x^2-y^2)$ will be the mean motion for the interval $x-y$ in the tables of Chriſnabouram. If, then, a be any other interval, as that of 43.83 centuries, the mean motion aſſigned to it, in theſe laſt tables, by the rule of proportion, will be $\frac{ma(x-y)-9''a(x^2-y^2)}{x-y} = ma-9a(x+y)$. Let this motion, actually taken from the ta-

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28. THIS laſt is one of the few coincidences between the aſtronomy of India and of Europe, which their ingenious hiſtorian has left for others to obſerve. Indeed, ſince he wrote, every argument, founded on the moon's acceleration, has become more worthy of attention, and more concluſive. For that acceleration is no longer a mere empyrical equation, introduced to reconcile the ancient obſervations with the modern, nor a fact that can only be accounted for by hypothetical cauſes, ſuch as the reſiſtance of the ether, or the time neceſſary for the tranſmiſſion of gravity; it is a phenomenon, which M. DE LA PLACE has *, with great ability, deduced from the principle of univerſal gravitation, and ſhewn to be neceſſarily connected with the changes in the eccentricity of the earth's orbit, diſcovered by M. DE LA GRANGE; ſo that the acceleration of the moon is indirectly produced by the action of the planets, which alternately increaſing and diminiſhing the ſaid eccentricity, ſubjects the moon to different degrees of that force by which the ſun diſturbs the time of her revolution round the earth. It is therefore a periodical inequality, by which the moon's motion, in the courſe of ages, will be as much retarded as accelerated; but its changes are ſo ſlow, that her motion has been conſtantly accelerated, even for a longer period than that to which the obſervations of India extend.

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bles be $= na$, then $ma - na = 9a(x+y)$, or $x+y = \frac{m-n}{g} = 52.19$, in the preſent caſe. It is certain, therefore, that whatever ſuppoſition be made with reſpect to the interval between x and y, their ſum muſt always be the ſame, and muſt amount to 5219 years. But that, that interval may be long enough to give the mean motions with exactneſs, it can ſcarcely be ſuppoſed leſs than 2000 years; and, in that caſe, $x = 3609$ years, which therefore is its leaſt value. But if 3609 be reckoned back from 1700, it goes up to 1909 years before CHRIST, nearly, as has been ſaid.

IT muſt be remembered, that what is here inveſtigated is the limit, or the moſt modern date poſſible to be aſſigned to the obſervations in queſtion. The ſuppoſition that $x - y = a$, is the moſt probable of all, and it gives $x = 4801$, which correſponds to the beginning of the Calyougham.

* Mem. Acad. des Scien. 1786, p. 235, &c.

A FORMULA for computing the quantity of this inequality, has been given by M. DE LA PLACE, which, though only an approximation, being derived from theory, is more accurate than that which MAYER deduced entirely from obſervation * ; and if it be taken inſtead of MAYER's, which laſt, on account of its ſimplicity, I have employed in the preceding calculations, it will give a quantity ſomewhat different, though not ſuch as to affect the general reſult. It makes the acceleration for 4383 years, dated from the beginning of the Calyougham, to be greater by 17′, 39″, than was found from MAYER's rule, and greater conſequently by 16′, 32″, than was deduced from the tables of Chriſnabouram. It is plain, that this coincidence is ſtill near enough to leave the argument, that is founded on it, in poſſeſſion of all its force, and to afford a ſtrong confirmation of the accuracy of the theory, and the authenticity of the tables.

THAT obſervations made in India, when all Europe was barbarous or uninhabited, and inveſtigations into the moſt ſubtle effects of gravitation made in Europe, near five thouſand years afterwards, ſhould thus come in mutual ſupport of one another, is perhaps the moſt ſtriking example of the progreſs and viciſſitude of ſcience, which the hiſtory of mankind has yet exhibited.

29. THIS, however, is not the only inſtance of the ſame kind that will occur, if, from examining the radical places and mean motions in the Indian aſtronomy, we proceed to conſider ſome other of its elements, ſuch as, the length of the year, the inequality of the ſun's motion, and the obliquity of the ecliptic, and compare them with the concluſions deduced, from the theory of gravity, by M. DE LA GRANGE. To that geometer, phyſical aſtronomy is indebted for one of the moſt beautiful of its diſcoveries, *viz.* That all the variations in our ſyſtem are periodical; ſo that though every thing, almoſt without exception,

* Mem. Acad. des Scien. 1786, p. 260.

tion, be ſubject to change, it will, after a certain interval, return to the ſame ſtate in which it is at preſent, and leave no room for the introduction of diſorder, or of any irregularity that might conſtantly increaſe. Many of theſe periods, however, are of vaſt duration. A great number of ages, for inſtance, muſt elapſe before the year be again exactly of the ſame length, or the ſun's equation of the ſame magnitude as at preſent *. An aſtronomy, therefore, which profeſſes to be ſo ancient as the Indian, ought to differ conſiderably from ours in many of its elements. If indeed theſe differences are irregular, they are the effects of chance, and muſt be accounted errors; but if they obſerve the laws, which theory informs us that the variations in our ſyſtem do actually obſerve, they muſt be held as the moſt undoubted marks of authenticity. We are to examine, as M. BAILLY has done, which of theſe takes place in the caſe before us †.

30. THE tables of Tirvalore, which, as we have ſeen, refer their date to the beginning of the Calyougham, make the ſyderial year to conſiſt of 365^d, 6^h, 12′, 30″; and therefore the tropical of 365^d, 5^h, 50′, 35″, which is 1′, 46″, longer than that of DE LA CAILLE ‡. Now, the tropical year was in reality longer at that time than it is at preſent; for though the ſiderial year, or the time which the earth takes to return from one point of ſpace to the ſame point again, is always of the ſame magnitude, yet the tropical year being affected by the preceſſion of the equinoxes, is variable by a ſmall quantity, which never can exceed 3′, 40″, and which is ſubject to ſlow, and unequal alternations of diminution and increaſe. A theorem, expreſſing the law and the quantity of this variation, has been inveſtigated by M. DE LA GRANGE, in the excellent Memoir

* Mem. de l'Acad. de Berlin, 1782, p. 170, &c.

† Aſt. Ind. p. 160, &c.

‡ Supra, § 18. and 10.

moir already mentioned *; and it makes the year 3102 before CHRIST, $40''\frac{1}{7}$ longer than the year at the beginning of the present century †. The year in the tables of Tirvalore is therefore too great by $1'$, $5''\frac{1}{2}$.

31. BUT the determination of the year is always from a comparison of observations made at a considerable interval from one another; and, even to produce a degree of accuracy much less than what we see belongs to the tables of Tirvalore, that interval must have been of several ages. Now, says M. BAILLY, if we suppose these observations to have been made in that period of 2400 years, immediately preceding the Calyougham, to which the Brahmins often refer; and if we also suppose the inequality of the precession of the equinoxes, to increase as we go back, in proportion to the square of the times, we shall find, that, at the middle of this period, or 1200 years before the beginning of the Calyougham, the length of the year was 365^d, 5^h, $50'$, $41''$, almost precisely as in the tables of Tirvalore. And hence it is natural to conclude, that this determination of the solar year is as ancient as the year 1200 before the Calyougham, or 4300 before the Christian era ‡.

32. IN this reasoning, however, it seems impossible to acquiesce; and M. BAILLY himself does not appear to have relied on it with much confidence ‖. We are not at liberty to suppose, that the precession of the equinoxes increases in the ratio above mentioned, or, which is the same, that the equinoctial points go back with a motion equably retarded. If, by M. DE GRANGE's formula, we trace back, step by step, the variation of the solar year, we shall find, that about the beginning of the Calyougham, it had nearly attained the extreme point of one

* Mem. Acad. Berlin, 1782. p. 289.

† Ast. Ind. p. 160.

‡ Ibid. p. 161.

‖ HE says, "Sans doute il ne peut résulter de ce calcul qu'un apperçu."

one of thoſe vibrations, which many centuries are required to complete; and that the year was then longer than it has ever been ſince, or than it had been for many ages before. It was 40″½ longer than it is at preſent; but, at the year 5500 before CHRIST, it was only 29″ longer than at preſent, inſtead of 2′, 50″, which is the reſult of M. BAILLY's ſuppoſition. During all the intervening period of 2400 years, the variation of the year was between theſe two quantities; and we cannot therefore, by any admiſſible ſuppoſition, reduce the error of the tables to leſs than 1′, 5″. The ſmallneſs of this error, though extremely favourable to the antiquity, as well as the accuracy of the Indian aſtronomy, is a circumſtance from which a more preciſe concluſion can hardly be deduced.

33. THE equation of the ſun's centre is an element in the Indian aſtronomy, which has a more unequivocal appearance of belonging to an earlier period than the Calyougham. The maximum of that equation is fixed, in theſe tables, at 2°, 10′, 32″. It is at preſent, according to M. DE LA CAILLE, 1°, 55′½, that is, 15′ leſs than with the Brahmins. Now, M. DE LA GRANGE has ſhewn, that the ſun's equation, together with the eccentricity of the earth's orbit, on which it depends, is ſubject to alternate diminution and increaſe, and accordingly has been diminiſhing for many ages. In the year 3102 before our era, that equation was 2°, 6′, 28″½; leſs, only by 4′, than in the tables of the Brahmins. But if we ſuppoſe the Indian aſtronomy to be founded on obſervations that preceded the Calyougham, the determination of this equation will be found to be ſtill more exact. Twelve hundred years before the commencement of that period, or about 4300 years before our era, it appears, by computing from M. DE LA GRANGE's formula, that the equation of the ſun's centre was actually 2°, 8′, 16″; ſo that if the Indian aſtronomy be as old as that period, its error with reſpect to this equation is but of 2′ *.

x 2 34. THE

* Aſt. Ind. p. 163.

34. THE obliquity of the ecliptic is another element in which the Indian aſtronomy and the European do not agree, but where their difference is exactly ſuch as the high antiquity of the former is found to require. The Brahmins make the obliquity of the ecliptic 24°. Now, M. DE LA GRANGE's formula for the variation of the obliquity *, gives 22′, 32″, to be added to its obliquity in 1700, that is, to 23°, 28′, 41″, in order to have that which took place in the year 3102 before our era. This gives us 23°, 51′, 13″, which is 8′, 47″, ſhort of the determination of the Indian aſtronomers. But if we ſuppoſe, as in the caſe of the ſun's equation, that the obſervations on which this determination is founded, were made 1200 years before the Calyougham, we ſhall find that the obliquity of the ecliptic was 23°, 57′, 45″, and that the error of the tables did not much exceed 2′ †.

35. THUS, do the meaſures which the Brahmins aſſign to theſe three quantities, the length of the tropical year, the equation of the ſun's centre, and the obliquity of the ecliptic, all agree in referring the epoch of their determination to the year 3102 before our era, or to a period ſtill more ancient. This coincidence in three elements, altogether independent of one another, cannot be the effect of chance. The difference, with reſpect to each of them, between their aſtronomy and ours, might ſingly perhaps be aſcribed to inaccuracy; but that three errors, which chance had introduced, ſhould be all of ſuch magnitudes, as to ſuit exactly the ſame hypotheſis concerning their origin, is hardly to be conceived. Yet there is no other alternative, but to admit this very improbable ſuppoſition, or to acknowledge that the Indian aſtronomy is as ancient as one, or other of the periods above mentioned.

36. THIS concluſion would receive great additional confirmation, could we follow M. BAILLY in his analyſis of the aſtronomy

* Mem. Acad. Berlin, 1782, p. 287.

† Aſt. Ind. p. 165.

nomy of the planets, contained in the tables of Chriſnabouram *; but the length to which this *paper* is already extended, will allow only a few of the moſt remarkable particulars to be ſelected.

In theſe tables, which are for the epoch 1491, the mean motions are given with conſiderable accuracy, but without an appearance of being taken from Ptolemy, or any of the aſtronomers already mentioned. Two inequalities, called the *ſchigram* and the *manda*, are alſo diſtinguiſhed in each of the planets, both ſuperior and inferior †. The firſt of theſe is the ſame with that which we call the parallax of the earth's orbit, or the apparent inequality of a planet, which ariſes not from its own motion, but from that of the obſerver; but whether it is aſcribed, in the Indian aſtronomy, to its true cauſe, or to the motion of the planet in an epicycle, is a queſtion about which the tables give no direct information. The magnitude, however, of this equation is aſſigned, for each of the planets, with no ſmall exactneſs, and is varied, in the different points of its orbit, by a law which approaches very near to the truth.

The other inequality coincides with that of the planet's centre, or that which ariſes from the eccentricity of its orbit, and it is given near the truth for all the planets, except Mercury, by which, as is no wonder, the firſt aſtronomers were, every where, greatly deceived. Of this inequality, it is ſuppoſed, juſt as in the caſes of the ſun and moon, that it is always as the ſine of the planet's diſtance from the point of its sloweſt motion, or from what we call its aphelion, and is conſequently greateſt at 90° from that point.

It were to be wiſhed that we knew the etymology of the names which are given to theſe inequalities, as it might explain the theory which guided the authors of the tables. The titles of our aſtronomical tables, the terms *aphelion*, *heliocentric* or

* Aſt. Ind. p. 173, &c.

† Ibid. p. 177.

or *geocentric place*, &c. would diſcover the leading ideas of the Copernican ſyſtem, were no other deſcription of it preſerved.

37. In the manner of applying theſe two inequalities, to correct the mean place of a planet, the rules of this aſtronomy are altogether ſingular. In the caſe of a ſuperior planet, they do not make uſe of the mean anomaly, as the argument for finding out the equation *manda*, but of that anomaly, when corrected firſt by half the equation *ſchigram*, and afterwards by half the equation *manda* *. By the equation of the centre, obtained with this argument, the mean longitude of the planet is corrected, and its true heliocentric place conſequently found, to which there is again applied the parallax of the annual orbit, that the geocentric place may be obtained. The only difficulty here, is in the method of taking out from the tables the equation to the centre. It is evidently meant for avoiding ſome inaccuracy, which was apprehended from a more direct method of calculation, but of which, even after the ingenious remarks of M. Bailly, it ſeems impoſſible to give any clear and ſatisfactory account.

38. The manner of calculating the places of the inferior planets has a great reſemblance to the former; with this difference, however, that the equation *manda*, or of the centre, is applied to correct, not the mean place of the planet, but the mean place of the ſun; and to this laſt, when ſo corrected, is applied the equation *ſchigram*, which involves the planet's elongation from the ſun, and gives its geocentric place †. This neceſſarily implies, that the centre, about which the inferior planets revolve, has the ſame apparent mean motion with the ſun: but whether it be a point really different from the ſun, or the ſame; and, if the ſame, whether it be in motion or at reſt, are left entirely undetermined, and we know not, whether, in the aſtronomy of India, we have here diſcovered a reſemblance

* Aſt. Ind. p. 194.

† Ibid. p. 199, &c.

blance to the Ptolemaic, the Tychonic, or the Copernican ſyſtem.

39. THESE tables, though their radical places are for the year 1491 of our era, have an obvious reference to the great epoch of the Calyougham. For if we calculate the places of the planets from them, for the beginning of the aſtronomical year, at that epoch, we find them all in conjunction with the ſun in the beginning of the moveable zodiac, their common longitude being 10ˢ, 6° *. According to our tables, there was, at that time, a conjunction of all the planets, except Venus, with the ſun; but they were, by no means, ſo near to one another as the Indian aſtronomy repreſents. It is true, that the exact time of a conjunction cannot be determined by direct obſervation: but this does not amount to an entire vindication of the tables; and there is reaſon to ſuſpect, that ſome ſuperſtitious notions, concerning the beginning of the Calyougham, and the ſigns by which nature muſt have diſtinguiſhed ſo great an epoch, has, in this inſtance at leaſt, perverted the aſtronomy of the Brahmins. There are, however, ſome coincidences between this part of their aſtronomy, and the theory of gravity, which muſt not be forgotten.

40. THE firſt of theſe reſpects the aphelion of Jupiter, which, in the tables, is ſuppoſed to have a retrograde motion of 15° in 200,000 years †, and to have been, at the epoch of 1491, in longitude 5ˢ, 21°, 40′, 20″, from the beginning of the zodiac. It follows, therefore, that in the year 3102 before CHRIST, the longitude of Jupiter's aphelion was 3ˢ, 27°, 0′, reckoned from the equinox. Now, the ſame, computed from M. DE LA LANDE's tables, is only 3ˢ, 16°, 48′, 58″; ſo that there would ſeem to be an error of more than 10° in the tables of the Brahmins. But, if it be conſidered, that Jupiter's orbit is

* Aſt. Ind. p. 181.

† Ibid. p. 184. § 13.

is ſubject to great diſturbances, from the action of Saturn, which M. DE LA LANDE does not profeſs to have taken into account, we will be inclined to appeal once more to M. DE LA GRANGE's formulas, before we paſs ſentence againſt the Indian aſtronomy *.

FROM one of theſe formulas, we find, that the true place of the aphelion of Jupiter, at the time above mentioned, was 3^s, 26°, 50′, 40″, which is but 10′, 40″, different from the tables of Chriſnabouram. The French and Indian tables are therefore both of them exact, and only differ becauſe they are adapted to ages near five thouſand years diſtant from one another.

41. THE equation of Saturn's centre is an inſtance of the ſame kind. That equation, at preſent, is, according to M. DE LA LANDE, 6°, 23′, 19″; and hence, by means of one of the formulas above mentioned, M. BAILLY calculates, that, 3102 years before CHRIST, it was 7°, 41′, 22″ †. The tables of the Brahmins make it 7°, 39′, 44″, which is leſs only by 1′, 38″, than the preceding equation, though greater than that of the preſent century by 1°, 16′, 25″.

42. M. BAILLY remarks, that the equations for the other planets are not given with equal accuracy, and afford no more ſuch inſtances as the former. But it is curious to obſerve, that new reſearches into the effects of gravitation, have diſcovered new coincidences of the ſame kind; and that the two great geometers, who have ſhared between them the glory of perfecting the *theory of diſturbing forces*, have each contributed his part to eſtabliſh the antiquity of the Indian aſtronomy. Since the publication of M. BAILLY's work, two other inſtances of an exact agreement, between the elements of theſe tables, and the concluſions deduced from the theory of gravity, have been obſerved, and communicated to him by M. DE LA PLACE, in a letter, inſerted in the *Journal des Savans*.

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* Mem. Acad. Berlin. 1782, p. 246. Aſt. Ind. p. 186.

† Aſt. Ind. p. 188.

In ſeeking for the cauſe of the ſecular equations, which modern aſtronomers have found it neceſſary to apply to the mean motion of Jupiter and Saturn, M. de la Place has diſcovered, that there are inequalities belonging to both theſe planets, ariſing from their mutual action on one another, which have long periods, one of them no leſs than 877 years; ſo that the mean motion muſt appear different, if it be determined from obſervations made in different parts of thoſe periods. "Now, "I find," ſays he, "by my theory, that at the Indian epoch "of 3102 years before Christ, the apparent and annual "mean motion of Saturn was 12°, 13′, 14″, and the Indian "tables make it 12°, 13′, 13″.

"In like manner, I find, that the annual and apparent mean "motion of Jupiter at that epoch was 30°, 20′, 42″, preciſely "as in the Indian aſtronomy *."

43. Thus have we enumerated no leſs than nine aſtronomical elements †, to which the tables of India aſſign ſuch values as do, by no means, belong to them in theſe later ages, but ſuch as the theory of gravity proves to have belonged to them three thouſand years before the Chriſtian era. At that time, therefore, or in the ages preceding it, the obſervations muſt have been made from which theſe elements were deduced. For it is abundantly evident, that the Brahmins of later times, however willing they might be to adapt their tables to ſo remarkable an epoch as the Calyougham, could never think of doing ſo, by ſubſtituting, inſtead of quantities which they had obſerved, others which they had no reaſon to believe had ever exiſted. The elements in queſtion are preciſely what theſe

f   aſtronomers

* Eſprit des Journeaux, Nov. 1787. p. 80.

† The inequality of the preceſſion of the equinoxes, (§ 22.); the acceleration of the moon; the length of the ſolar year; the equation of the ſun's centre; the obliquity of the ecliptic; the place of Jupiter's aphelion; the equation of Saturn's centre; and the inequalities in the mean motion of both theſe planets.

aſtronomers muſt have ſuppoſed invariable, and of which, had they ſuppoſed them to change, they had no rules to go by for aſcertaining the variations; ſince, to the diſcovery of theſe rules is required, not only all the perfection to which aſtronomy is, at this day, brought in Europe, but all that which the ſciences of motion and of extenſion have likewiſe attained. It is no leſs clear, that theſe coincidences are not the work of accident; for it will ſcarcely be ſuppoſed that chance has adjuſted the errors of the Indian aſtronomy with ſuch ſingular felicity, that obſervers, who could not diſcover the true ſtate of the heavens, at the age in which they lived, have ſucceeded in deſcribing one which took place ſeveral thouſand years before they were born.

44. THE argument, however, which regards the originality of theſe tables, is, in ſome meaſure, incomplete, till we have conſidered the geometrical principles which have been employed in their conſtruction. For it is not impoſſible, that when ſeen connected by thoſe principles, and united into general theorems, they may be found to have relations to the Greek aſtronomy, which did not appear, when the parts were examined ſingly. On this ſubject, therefore, I am now to offer a few obſervations.

45. THE rules by which the phenomena of eclipſes are deduced from the places of the ſun and moon, have the moſt immediate reference to geometry; and of theſe rules, as found among the Brahmins of Tirvalore, M. LE GENTIL has given a full account, in the Memoir that has been ſo often quoted. We have alſo an account of the method of calculation uſed at Chriſnabouram by Father DU CHAMP *.

IT is a neceſſary preparation, in both of theſe, to find the time of the ſun's continuance above the horizon, at the place and the day for which the calculation of an eclipſe is made, and the rule by which the Brahmins reſolve this problem, is extremely ſimple and

* Aſt. Ind. p. 355, &c.

and ingenious. At the place for which they calculate, they obſerve the ſhadow of a gnomon on the day of the equinox, at noon, when the ſun, as they expreſs it, is in the middle of the world. The height of the gnomon is divided into 720 equal parts, in which parts the length of the ſhadow is alſo meaſured. One third of this meaſure is the number of minutes by which the day, at the end of the firſt month after the equinox, exceeds twelve hours; four-fifths of this exceſs is the increaſe of the day during the ſecond month; and one third of it is the increaſe of the day, during the third month *.

46. It is plain, that this rule involves the ſuppoſition, that, when the ſun's declination is given, the ſame ratio every where exiſts between the arch which meaſures the increaſe of the day at any place, and the tangent of the latitude; for that tangent is the quotient which ariſes from dividing the length of the ſhadow by the height of the gnomon. Now, this is not ſtrictly true; for ſuch a ratio only ſubſiſts between the chord of the arch, and the tangent above mentioned. The rule is, therefore, but an approximation to the truth, as it neceſſarily ſuppoſes the arch in queſtion to be ſo ſmall as to coincide nearly with its chord. This ſuppoſition holds only of places in low latitudes; and the rule which is founded on it, though it may ſafely be applied in countries between the tropics, in thoſe that are more remote from the equator, would lead into errors too conſiderable to eſcape obſervation †.

 As

* Mem. Acad. des Scien. II. P. 175.

† To judge of the accuracy of this approximation, ſuppoſe O to be the obliquity of the ecliptic, and x the exceſs of the ſemidiurnal arch, on the longeſt day, above an arch of 90°, then $\sin . x = \tan . O \times \tan . lat.$ But if G be the height of a gnomon, and S the length of its ſhadow on the equinoctial day, $\frac{S}{G} = \tan . lat.$ and $\sin . x = \tan . O \times \frac{S}{G}$.

Therefore $x = \tan . O \times \frac{S}{G} + \frac{\tan . O^3 \times S^3}{6G^3} + \frac{\tan . O^5 \times S^5}{24G^5} +$ &c. or in minutes of

time,

As ſome of the former rules, therefore, have ſerved to fix the time, ſo does this, in ſome meaſure, to aſcertain the place of its invention. It is the ſimplification of a general rule, adapted to the circumſtances of the torrid zone, and ſuggeſted to the aſtronomers of Hindoſtan by their peculiar ſituation. It implies the knowledge of the circles of the ſphere, and of ſpherical trigonometry, and perhaps argues a greater progreſs in mathematical reaſoning, than a theorem that was perfectly accurate would have done. The firſt geometers muſt naturally have dreaded nothing ſo much as any abatement in the rigour of their demonſtrations, becauſe they would ſee no limits to the error and uncertainty, in which they might, by that means, be involved. It was long before the mathematicians of Greece underſtood how to ſet bounds to ſuch errors, and to aſcertain their utmoſt extent, whether on the ſide of exceſs or defect; in this art, they appear to have received the firſt leſſons ſo late as the age of ARCHIMEDES.

47. THE

time, reckoned after the Indian manner, $x = 572.957\left(tan.O \times \frac{S}{G} + tan.O^3 \times \frac{S^3}{6G^3} + \&c.\right)$

IF $O = 24°$, then $tan.O = .4452$, and the firſt term of this formula gives $x = 572.957 \times \frac{.4452S}{G} = \frac{255S}{G}$, which is the ſame with the rule of the Brahmins.

FOR that rule, reduced into a formula, is $2x = \frac{720S}{G}\left(\frac{1}{3} + \frac{4}{15} + \frac{1}{9}\right) = \frac{512S}{G}$, or $x = \frac{256S}{G}$.

THEY have therefore computed the coefficient of $\frac{S}{G}$ with ſufficient accuracy; the error produced by the omiſſion of the reſt of the terms of the ſeries will not exceed 1′, even at the tropics, but, beyond them, it increaſes faſt, and, in the latitude of 45°, would amount to 8′.

47. The Brahmins having thus obtained the variations of the length of the day, at any place, or what we call the aſcenſional differences, apply them likewiſe to another purpoſe. As they find it neceſſary to know the point of the ecliptic, which is on the horizon, at the time when an eclipſe happens, they have calculated a table of the right aſcenſions of the points of the ecliptic in time, to which they apply the aſcenſional differences for the place in queſtion, in order to have the time which each of the ſigns takes to deſcend below the horizon of that place *. This is exactly the method, as is well known, which the moſt ſkilful aſtronomer, in like circumſtances, would purſue. Their table of the differences of right aſcenſion is but for a few points in the ecliptic, *viz.* the beginning of each ſign, and is only carried to minutes of time, or tenths of a degree. It is calculated, however, ſo far as it goes, with perfect accuracy, and it ſuppoſes the obliquity of the ecliptic, as before, to be twenty-four degrees.

Such calculations could not be made without ſpherical trigonometry, or ſome method equivalent to it. If, indeed, we would allow the leaſt ſkill poſſible to the authors of theſe tables, we may ſuppoſe, that the arches were meaſured on the circles of a large globe, or armillary ſphere, ſuch as we know to have been one of the firſt inſtruments of the Egyptian and Greek aſtronomers. But there are ſome of the tables where the arches are put down true to ſeconds, a degree of accuracy which a mechanical method can ſcarcely have afforded.

48. In another part of the calculation of eclipſes, a direct application is made of one of the moſt remarkable propoſitions in geometry. In order to have the ſemiduration of a ſolar eclipſe, they ſubtract from the ſquare of the ſum of the ſemidiameters of the ſun and moon, the ſquare of a certain line, which is a perpendicular from the centre of the ſun on the path of the moon; and from the remainder, they extract the

* Acad. des Scien. 1772, II. P. 205.

the ſquare root, which is the meaſure of the ſemiduration *. The ſame thing is practiſed in lunar eclipſes †. Theſe operations are all founded on a very diſtinct conception of what happens in the caſe of an eclipſe, and on the knowledge of this theorem, that, in a right-angled triangle, the ſquare on the hypothenuſe is equal to the ſquares on the other two ſides. It is curious to find the theorem of PYTHAGORAS in India, where, for aught we know, it may have been diſcovered, and from whence that philoſopher may have derived ſome of the ſolid, as well as the viſionary ſpeculations, with which he delighted to inſtruct or amuſe his diſciples.

49. WE have mentioned the uſe that is made of the ſemidiameters of the ſun and moon in theſe calculations, and the method of aſcertaining them, is deſerving of attention. For the ſun's apparent diameter, they take four-ninths of his diurnal motion, and for the moon's diameter, one twenty-fifth of her diurnal motion. In an eclipſe, they ſuppoſe the ſection of the ſhadow of the earth, at the diſtance of the moon, to have a diameter five times that of the moon; and in all this, there is conſiderable accuracy, as well as great ſimplicity. The apparent diameters of the ſun and moon, increaſe and diminiſh with their angular velocities; and though there be a miſtake in ſuppoſing, that they do ſo exactly in the ſame proportion, it is one which, without teleſcopes and micrometers, cannot eaſily be obſerved. The ſection of the earth's ſhadow, likewiſe, if the ſun's apparent diameter be given, increaſes as the moon's increaſes, or as her diſtance from the earth diminiſhes, and nearly enough in the ſame ratio to juſtify the rule which is here laid down.

50. THE hiſtorian of the Academy of Sciences, in giving an account of M. LE GENTIL's Memoir, has juſtly obſerved, that the

* Mem. Acad. des Scien. 1772, II. P. 259.

† Ibid. 241.

the rule deſcribed in it, for finding the difference between the true and apparent conjunction, at the time of a ſolar eclipſe, contains the calculation of the moon's parallax, but ſubſtitutes the parallax in right aſcenſion for the parallax in longitude *; an error which the authors of this aſtronomy would probably have avoided, had they derived their knowledge from the writings of PTOLEMY. From this ſuppoſed parallax in longitude, they next derive the parallax in latitude, where we may obſerve an application of the doctrine of ſimilar triangles; for they ſuppoſe the firſt of theſe to be to the laſt in the conſtant ratio of 25 to 2, or nearly as the radius to the tangent of the inclination of the moon's orbit to the plane of the ecliptic. We have here, therefore, the application of another geometrical theorem, and that too proceeding on the ſuppoſition, that a ſmall portion of the ſphere, on each ſide of the point which the ſun occupies at the middle of the eclipſe, may be held to coincide with a plane touching it in that point.

51. THE reſult which the Brahmins thus obtain will be allowed to have great accuracy, if it be conſidered how ſimple their rules are, and how long it muſt be ſince their tables were corrected by obſervations. In two eclipſes of the moon, calculated in India by their method, and likewiſe obſerved there by M. LE GENTIL, the error, in neither caſe, exceeded 23′ of time, (correſponding to one of 13′ of a degree, in the place of the moon); and in the duration and magnitude of the eclipſe, their calculation came ſtill nearer to the truth †.

52. SINCE

* Hiſt. Acad. II. P. 109. Ibid. Mem. 253,—256.

† IN the language, however, of their rules, we may trace ſome marks of a fabulous and ignorant age, from which indeed even the aſtronomy of Europe is not altogether free. The place of the moon's aſcending node, is with them *the place of the Dragon* or *the Serpent*; the moon's diſtance from the node, is literally tranſlated by M. LE GENTIL, *la*

52. SINCE an inequality was first observed in the motions of the sun or moon, the discovery of the law which it follows, and the method of determining the quantity of it, in the different points of their orbits, has been a problem of the greatest importance; and it is curious to inquire, in what manner the astronomers of India have proceeded to resolve it. For this purpose, we must examine the tables of the *chaiaa*, or equations of the centre for the sun and moon, and of the *manda*, or equations of the centre for the planets. With respect to the first, as contained in the tables of Siam, M. CASSINI observed, that the equations followed the ratio of the sines of the mean distances from the apogee; but as they were calculated only for a few points of the orbit, it could not be known with what degree of exactness this law was observed. Here, however, the tables of Chrisnabouram remove the uncertainty, as they give the equation of the centre for every degree of the mean motion, and make it nearly as the sine of the distance from the apogee.

THEY do so, however, only nearly; and it will be found on trial, that there is, in the numbers of the table, a small, but regular variation from this law, which is greatest when the argument is 30°, though even there it does not amount to a minute. The sun's equation, for instance, which, when greatest, or when the argument is 90°, is, by these tables, 2°, 10′, 32″, should be, when the argument is 30°, just the half of this, or 1°, 5′, 16″, did the numbers in the table follow exactly the ratio

la lune offensée du dragon. Whether it be that we have borrowed these absurdities from India, along with astrology, or if the popular theory of eclipses has, at first, been every where the same, the moon's node is also known with us by the name of the *cauda draconis.* In general, however, the signification of the terms in these rules, so far as we know it, is more rational. In one of them we may remark considerable refinement; *ayanangsam,* which is the name for the reduction made on the sun's longitude, on account of the precession of the equinoxes, is compounded from *ayanam,* a *course,* and *angsam,* an *atom.* Mem. Acad. II. P. 251. The equinox is almost the only point not distinguished by a visible object, of which the *course* or motion is computed in this astronomy.

ratio of the ſines of the argument. It is, however, 1°, 6′, 3″; and this exceſs of 47″ cannot have ariſen from any miſtake about the ratio of the ſine of 30° to that of 90°, which is ſhewn to be that of 1 to 2, by a propoſition in geometry * much too ſimple to have been unknown to the authors of theſe tables. The rule, therefore, of the equations, being proportional exactly to the ſines of the argument, is not what was followed, or intended to be followed, in the calculation of them. The differences, alſo, between the numbers computed by that rule, and thoſe in the tables, are perfectly regular, decreaſing from the point of 30°, both ways toward the beginning and end of the quadrant, where they vaniſh altogether.

THESE obſervations apply alſo to the tables of Narſapur †, and to the moon's equations, as well as to the ſun's, with a circumſtance, however, which is not eaſily accounted for, *viz.* that the differences between the numbers calculated by M. CASSINI's rule, and thoſe in the tables, are not greater in the caſe of the moon than of the ſun, though the equation of the latter be more than double that of the former. They apply alſo to the tables *manda* of the planets, where the equations are greater than the ratio of the ſines of their arguments requires, the exceſs being greateſt at 30°, and amounting to ſome minutes in the equations of Saturn, Jupiter and Mars, in which laſt it is greateſt of all.

53. THOUGH, for theſe reaſons, it is plain, that the rule of M. CASSINI is not the ſame with that of the Brahmins, it certainly includes the greater part of it; and if the latter, whatever it may have been, were expreſſed in a ſeries, according to the methods of the modern analyſis, the former would be the firſt term of that ſeries. We are not, however, much advanced in our inquiry in conſequence of this remark; for the firſt terms of all the ſeries, which can, on any hypotheſis, expreſs the

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* Euc. Lib. IV. Prop. 15.

† See theſe tables, Aſt. Ind. p. 414.

the relation of the equation of the centre to the anomaly of a planet, are ſo far the ſame, that they are proportional to the ſine of that anomaly; and it becomes therefore neceſſary to ſearch among theſe hypotheſes, for that by which the ſeries of ſmall differences, deſcribed above, may be beſt repreſented. It is needleſs to enter here into any detail of the reaſonings by which this has been done, and by which I have found, that the argument in the table bears very nearly the ſame relation to the correſponding numbers, that the anomaly of the eccentric does to the equation of the centre. By the anomaly of the eccentric, however, I do not mean the angle which is known by that name in the ſolution of KEPLER's problem, but that which ſerves the ſame purpoſe with it, on the ſuppoſition of a circular orbit, and an uniform angular motion about a point which is not the centre of that orbit, but which is as diſtant from it, on the one ſide, as the earth (or the place of the obſerver) is on the other. It is the angle, which, in ſuch an orbit, the line drawn from the planet to the centre, makes with the line drawn from thence to the apogee; and the argument in the Indian tables coincides with this angle.

THIS hypotheſis of a double eccentricity, is certainly not the ſimpleſt that may be formed with reſpect to the motion of the heavenly bodies, and is not what one would expect to meet with here; but it agrees ſo well with the tables, and gives the equations from the arguments ſo nearly, eſpecially for the moon and the planets, that little doubt remains of its being the real hypotheſis on which theſe tables were conſtructed *.

54. OF

* THE formula deduced from this hypotheſis, for calculating the equation of the centre from the anomaly of the eccentric, is the following: Let x be the equation of the centre, φ the anomaly of the eccentric, e the eccentricity of the orbit, or the tangent of half the greateſt equation; then $x = 2e\,\text{ſin.}\,\varphi + \frac{2e^3\,\text{ſin.}\,3\varphi}{3} + \frac{2e^5\,\text{ſin.}\,5\varphi}{5} + \&c.$

54. Of this, the method employed to calculate the place of any of the five planets from these tables, affords a confirmation. But, in reasoning about that method, it is necessary to put out of the question the use that is made of the parallax of the annual orbit, or of the *schigram*, in order to have the argument for finding the equation of the centre, which is evidently faulty, as it makes that equation to be affected by a quantity, (the parallax of the annual orbit), on which it has in reality no dependence. To have the rule free from error, it is to be taken, therefore, in the case when there is no parallax of the annual orbit, that is, when the planets are in opposition or conjunction with the sun. In that case, the mean anomaly is first corrected by the subtraction or addition of half the equation that belongs to it in the table. It then becomes the true argument for finding, from that same table, the equation of the centre, which is next applied to the mean anomaly, to have the true. Now, this agrees perfectly with the conclusion above; for the mean anomaly, by the subtraction or addition of half the equation belonging to it in the table, is converted, almost precisely, into the anomaly of the eccentric, and becomes therefore the proper argument for finding out the equation, which is to change the mean anomaly into the true *. There can be no doubt, of consequence, that the conclusion we have come to is strictly applicable to the planets, and that the orbit of each of them, in this astronomy, is supposed to be a circle, the earth not being in its centre, but the angular velocity

* This method of calculation is so nearly exact, that even in the orbit of Mars, the equation calculated from the mean anomaly, rigorously on the principle of his angular motion being uniform, about a point distant from the centre, as described above, will rarely differ a minute from that which is taken out from the Indian tables by this rule. It was remarked, (§ 37.) that it is not easy to explain the rules for finding the argument of the equation of the centre, for the planets. What is said here explains fully one part of that rule, *viz.* the correction made by half the equation *manda*; the principle on which the other part proceeds, *viz.* the correction by half the equation *schigram*, is still uncertain.

velocity of the planet being uniform about a certain point, as far from that centre on the one ſide, as the earth is on the oppoſite.

55. Between the ſtructure of the tables of the equations of the ſun and moon, and the rules for uſing them, there is not the ſame conſiſtency; for in both of them, the argument, which we have found to be the eccentric anomaly, is, nevertheleſs treated as the mean. So far as concerns the ſun, this leads to nothing irreconcilable with our ſuppoſition, becauſe the ſun's equation being ſmall, the difference will be inconſiderable, whether the argument of that equation be treated as the eccentric or the mean anomaly.

But it is otherwiſe with reſpect to the moon, where the difference between conſidering the argument of the equation as the mean, or as the eccentric anomaly, is not inſenſible. The authority of the precepts, and of the tables, are here oppoſed to one another; and we can decide in favour of the latter, only becauſe it leads to a more accurate determination of the moon's place than the former. It would indeed be an improvement on their method of calculation, which the Brahmins might make conſiſtently with the principles of their own aſtronomy, to extend to the moon their rule for finding the equation of the centre for the planets. They would then avoid the palpable error of making the maximum of the moon's equation at the time when her mean anomaly is 90°, and would aſcertain her place every where with greater exactneſs. It is probable that this is the method which they were originally directed to follow.

56. From the hypotheſis which is thus found to be the baſis of the Indian aſtronomy, one of the firſt concluſions which preſents itſelf, is the exiſtence of a remarkable affinity between the ſyſtem of the Brahmins and that of Ptolemy. In the latter, the ſame thing was ſuppoſed for the five planets, that

that appears in the former to have been univerſally eſtabliſhed, *viz.* that their orbits were circles, having the earth within them, but removed at a ſmall diſtance from the centre, and that each planet deſcribed the circumference of its orbit, not with an uniform velocity, but with one that would appear uniform, if it were viewed from a point as far above the centre of the orbit, as that centre is above the earth. This point was, in the language of PTOLEMY's aſtronomy, the centre of the *Equant*.

NOW, concerning this coincidence, it is the more difficult to judge, as, on the one hand, it cannot be aſcribed to accident, and, on the other, it may be doubted, whether it ariſes neceſſarily out of the nature of the ſubject, or is a conſequence of ſome unknown communication between the aſtronomers of India and of Greece.

THE firſt hypotheſis by which men endeavoured to explain the phenomena of the celeſtial motions, was that of a uniform motion in a circle, which had the earth for its centre. This hypotheſis was, however, of no longer continuance than till inſtruments of tolerable exactneſs were directed to the heavens. It was then immediately diſcovered, that the earth was not the centre of this uniform motion; and the earth was therefore ſuppoſed to be placed at a certain diſtance from the centre of the orbit, while the planet revolved in the circumference of it with the ſame velocity as before. Both theſe ſteps may be accounted neceſſary; and in however many places of the earth, and however cut off from mutual intercourſe, aſtronomy had begun to be cultivated, I have no doubt that theſe two ſuppoſitions would have ſucceeded one another, juſt as they did among the Greek aſtronomers.

BUT when more accurate obſervations had ſhewn the inſufficiency even of this ſecond hypotheſis, what ought naturally to be the third, may be thought not quite ſo obvious; and if the Greeks made choice of that which has been deſcribed above, it may

may ſeem to have been owing to certain metaphyſical notions concerning the ſimplicity and perfection of a circular and uniform motion, which inclined them to recede from that ſuppoſition, no farther than appearances rendered abſolutely neceſſary. The ſame coincidence between the ideas of metaphyſics and aſtronomy, cannot be ſuppoſed to have taken place in other countries; and therefore, where we find this third hypotheſis to have prevailed, we may conclude that it was borrowed from the Greeks.

57. THOUGH it cannot be denied, that, in this reaſoning, there is ſome weight, yet it muſt be obſerved, that the introduction of the third hypotheſis did not reſt among the Greeks altogether on the coincidence above mentioned. It was one ſuited to their progreſs in mathematical knowledge, and offered almoſt the only ſyſtem, after the two former were exploded, which rendered the planetary motions the ſubject of geometrical reaſoning, to men little verſed in the methods of approximation. This was the circumſtance then, which, more than any other, probably influenced them in the choice of this hypotheſis, though we are not to look for it as an argument ſtated in their works, but may judge of the influence it had, from the frequency with which, many ages afterwards, the *αγεωμετρησια* of KEPLER's ſyſtem was objected to him by his adverſaries; an objection to which that great man ſeemed to pay more attention than it deſerved.

THERE is reaſon therefore to think, that in every country where aſtronomy and geometry had neither of them advanced beyond a certain point, the hypotheſis of the equant would ſucceed to that of a ſimple eccentric orbit, and therefore cannot be admitted as a proof, that the different ſyſtems in which it makes a part, are neceſſarily derived from the ſame ſource. Some other circumſtances attending this hypotheſis, as it is found in the Indian tables, go ſtill farther, and ſeem quite inconſiſtent with the ſuppoſition that the authors of theſe tables

derived

derived it from the aſtronomers of the weſt. For, *firſt*, It is applied by them to all the heavenly bodies, that is, to the ſun and moon, as well as the planets. With PTOLEMY, and with all thoſe who founded their ſyſtems on his, it extended only to the latter, inſomuch that KEPLER's great reformation in aſtronomy, the diſcovery of the elliptic orbits, began from his proving, that the hypotheſis of the equant was as neceſſary to be introduced for the ſake of the ſun's orbit, as for thoſe of the planets, and that the eccentricity in both caſes, muſt be biſected. It is, therefore, on a principle no way different from this of KEPLER, that the tables of the ſun's motion are computed in the Indian aſtronomy, though it muſt be allowed, that the method of uſing them is not perfectly conſiſtent with this idea of their conſtruction.

2dly, THE uſe made of the anomaly of the eccentric in theſe tables, as the argument of the equation of the centre, is altogether peculiar to the Indian aſtronomy. PTOLEMY's tables of that equation for the planets, though they proceed on the ſame hypotheſis, are arranged in a manner entirely different, and have for their argument the mean anomaly. The angle which we call the anomaly of the eccentric, and which is of ſo much uſe in the Indian tables, is not employed at all in the conſtruction of his *, nor, I believe, in thoſe of any other aſtronomer till the time of KEPLER; and even by KEPLER it was not made the argument of the equation to the centre. The method, explained above, of converting the mean anomaly into that of the eccentric, and conſequently into the argument of the equation, is another peculiarity, and though ſimple and ingenious, has not the accuracy ſuited to the genius of the Greek aſtronomy, which never admitted even of the beſt approximation, when a rigorous ſolution could be found; and, on the whole, if the reſemblance of theſe two ſyſtems, even with all the exceptions that have been ſtated, muſt ſtill be aſcribed

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* Almageſt. lib. XI. cap. 9. & 10.

to ſome communication between the authors of them, that communication is more likely to have gone from India to Greece, than in the oppoſite direction. It may perhaps be thought to favour this laſt opinion, that PTOLEMY has no where demonſtrated the neceſſity of aſſigning a double eccentricity to the orbits of the planets, and has left room to ſuſpect, that authority, more than argument, has influenced this part of his ſyſtem.

58. IN the tables of the planets, we remarked another equation, (*ſchigram*) anſwering to the parallax of the earth's orbit, or the difference between the heliocentric and the geocentric place of the planet. This parallax, if we conceive a triangle to be formed by lines drawn from the ſun to the earth and to the planet, and alſo from the planet to the earth, is the angle of that triangle, ſubtended by the line drawn from the ſun to the earth. And ſo, accordingly, it is computed in theſe tables; for if we reſolve ſuch a triangle as is here deſcribed, we will find the angle, ſubtended by the earth's diſtance from the ſun, coincide very nearly with the ſchigram.

THE argument of this equation is the difference between the mean longitude of the ſun and of the planet. The orbits are ſuppoſed circular; but whether the inequality in queſtion was underſtood to ariſe from the motion of the earth, or from the motion of the planet in an epicycle, the centre of which revolves in a circle, is left undetermined, as both hypotheſes may be ſo adjuſted as to give the ſame reſult with reſpect to this inequality. The proportional diſtances of the planets from the earth or the ſun, may be deduced from the tables of theſe equations, and are not far from the truth.

59. THE preceding calculations muſt have required the aſſiſtance of many ſubſidiary tables, of which no trace has yet been found in India. Beſides many other geometrical propoſitions, ſome of them alſo involve the ratio, which the diameter of a circle was ſuppoſed to bear to its circumference, but which

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we would find it impoſſible to diſcover from them exactly, on account of the ſmall quantities that may have been neglected in their calculations. Fortunately, we can arrive at this knowledge, which is very material when the progreſs of geometry is to be eſtimated, from a paſſage in the *Ayeen Akbery*, where we are told, that the Hindoos ſuppoſe the diameter of a circle to be to its circumference as 1250 to 3927 *, and where the author, who knew that this was more accurate than the proportion of ARCHIMEDES, (7 to 22), and believed it to be perfectly exact, expreſſes his aſtoniſhment, that among ſo ſimple a people, there ſhould be found a truth, which, among the wiſeſt and moſt learned nations, had been ſought for in vain.

THE proportion of 1250 to 3927 is indeed a near approach to the quadrature of the circle; it differs little from that of METIUS, 113 to 355, and is the ſame with one equally remarkable, that of 1 to 3.1416. When found in the ſimpleſt and moſt elementary way, it requires a polygon of 768 ſides to be inſcribed in a circle; an operation which cannot be arithmetically performed without the knowledge of ſome very curious properties of that curve, and, at leaſt, nine extractions of the ſquare root, each as far as ten places of decimals. All this muſt have been accompliſhed in India; for it is to be obſerved, that the above mentioned proportion cannot have been received from the mathematicians of the weſt. The Greeks left nothing on this ſubject more accurate than the theorem of ARCHIMEDES; and the Arabian mathematicians, ſeem not to have attempted any nearer approximation. The geometry of modern Europe can much leſs be regarded as the ſource of this knowledge. METIUS and VIETA were the firſt, who, in the quadrature of the circle, ſurpaſſed the accuracy of ARCHIMEDES; and they flouriſhed at the very time when the Inſtitutes of AKBAR were collected in India.

* Ayeen Akbery, Vol. III. p. 32.

60. On the grounds which have now been explained, the following general conclusions appear to be established.

I. The observations on which the astronomy of India is founded, were made more than three thousand years before the Christian era; and, in particular, the places of the sun and moon, at the beginning of the Calyougham, were determined by actual observation.

This follows from the exact agreement of the radical places in the tables of Tirvalore, with those deduced for the same epoch from the tables of De la Caille and Mayer, and especially in the case of the moon, when regard is had to her acceleration. It follows, too, from the position of the fixed stars in respect of the equinox, as represented in the Indian zodiac; from the length of the solar year; and, lastly, from the position and form of the orbits of Jupiter and Saturn, as well as their mean motions; in all of which, the tables of the Brahmins, compared with ours, give the quantity of the change that has taken place, just equal to that which the action of the planets on one another may be shown to have produced, in the space of forty-eight centuries, reckoned back from the beginning of the present.

Two other of the elements of this astronomy, the equation of the sun's centre, and the obliquity of the ecliptic, when compared with those of the present time, seem to point to a period still more remote, and to fix the origin of this astronomy 1000 or 1200 years earlier, that is, 4300 years before the Christian era; and the time necessary to have brought the arts of calculating and observing to such perfection as they must have attained at the beginning of the Calyougham, comes in support of the same conclusion.

Of such high antiquity, therefore, must we suppose the origin of this astronomy, unless we can believe, that all the coincidences

cidences which have been enumerated, are but the effects of chance; or, what indeed were ftill more wonderful, that, fome ages ago, there had arifen a NEWTON among the Brahmins, to difcover that univerfal principle which connects, not only the moft diftant regions of fpace, but the moft remote periods of duration; and a DE LA GRANGE, to trace, through the immenfity of both, its moft fubtle and complicated operations.

II. THOUGH the aftronomy which is now in the hands of the Brahmins, is fo ancient in its origin, yet it contains many rules and tables that are of later conftruction.

THE firft operation for computing the moon's place from the tables of Tirvalore, requires that 1,600,984 days fhould be fubtracted from the time that has elapfed fince the beginning of the Calyougham, which brings down the date of the rule to the year 1282 of our era. At this time, too, the place of the moon, and of her apogee, are determined with fo much exactnefs, that it muft have been done by obfervation, either at the inftant referred to, or a few days before or after it. At this time, therefore, it is certain, that aftronomical obfervations were made in India, and that the Brahmins were not, as they are now, without any knowledge of the principles on which their rules are founded. When that knowledge was loft, will not perhaps be eafily afcertained; but there are, I think, no circumftances in the tables from which we can certainly infer the exiftence of it at a later period than what has juft been mentioned; for though there are more modern epochs to be found in them, they are fuch as may have been derived from the moft ancient of all, by help of the mean motions in the tables of Chrifnabouram *, without any other fkill than is required to an ordinary calculation. Of thefe epochs, befide what have been occafionally mentioned in the courfe of our remarks, there is one (involved in the tables of Narfapur) as late as the year 1656, and another as early as the year 78 of our era, which

* Aft. Ind. p. 307.

which marks the death of SALIVAGANAM, one of their princes, in whose reign a reform is said to have taken place in the methods of their astronomy. There is no reference to any intermediate date, from that time to the beginning of the Calyougham.

THE parts of this astronomy, therefore, are not all of the same antiquity; nor can we judge, merely from the epoch to which the tables refer, of the age, to which they were originally adapted. We have seen, that the tables of Chrisnabouram, though they profess to be no older than the year 1491 of our era, are, in reality, more ancient than the tables of Tirvalore, which are dated from the Calyougham, or at least have undergone fewer alterations. This we concluded from the slow motion given to the moon, in the former of these tables, which agreed, with such wonderful precision, with the secular equation applied to that planet by MAYER, and explained by M. DE LA PLACE.

BUT it appears, that neither the tables of Tirvalore or Chrisnabouram, nor any with which we are yet acquainted, are the most ancient to be found in India. The Brahmins constantly refer to an astronomy at Benares, which they emphatically style *the ancient* *, and which they say is not now understood by them, though they believe it to be much more accurate than that by which they calculate. That it is more accurate, is improbable; that it may be more ancient, no one who has duly attended to the foregoing facts and reasonings, will think impossible; and every one, I believe, will acknowledge, that no greater service could be rendered to the learned world, than to rescue this precious fragment from obscurity. If that is ever to be expected, it is when the zeal for knowledge has formed a literary society among our countrymen in Bengal, and while that society is directed by the learning and abilities of Sir WILLIAM JONES. Indeed, the farther discoveries

* Ast. Ind. p. 309. M. LE GENTIL, Mem. Acad. Scien. 1772. P. II. p. 221.

ries which may be made with reſpect to this ſcience, do not intereſt merely the aſtronomer and the mathematician, but every one who delights to mark the progreſs of mankind, or is curious to look back on the ancient inhabitants of the globe. It is through the medium of aſtronomy alone that a few rays from thoſe diſtant objects can be conveyed in ſafety to the eye of a modern obſerver, ſo as to afford him a light, which, though it be ſcanty, is pure and unbroken, and free from the falſe colourings of vanity and ſuperſtition.

III. THE baſis of the four ſyſtems of aſtronomical tables which we have examined, is evidently the ſame.

THOUGH theſe tables are ſcattered over an extenſive country, they ſeem to have been all originally adapted, either to the ſame meridian, or to meridians at no great diſtance, which traverſe what we may call the claſſical ground of India, marked by the ruins of Canoge, Palibothra and Benares. They contain rules that have originated between the tropics; whatever be their epoch, they are all, by their mean motions, connected with that of the Calyougham; and they have beſides one uniform character which it is perhaps not eaſy to deſcribe. Great ingenuity has been exerted to ſimplify their rules; yet, in no inſtance almoſt, are they reduced to the utmoſt ſimplicity; and when it happens that the operations to which they lead are extremely obvious, theſe are often involved in an artificial obſcurity. A Brahmin frequently multiplies by a greater number than is neceſſary, where he ſeems to gain nothing but the trouble of dividing by one that is greater in the ſame proportion; and he calculates the era of SALIVAGANAM with the formality of as many diſtinct operations as if he were going to determine the moon's motion ſince the beginning of the Calyougham. The ſame ſpirit of excluſion, the ſame fear of communicating his knowledge, ſeems to direct the calculus which pervades the religion of the Brahmin; and, in neither of them, is he willing to receive or to impart inſtruction. With all theſe circumſtances of reſemblance,

blance, the methods of this aſtronomy are as much diverſified as we can ſuppoſe the ſame ſyſtem to be, by paſſing through the hands of a ſucceſſion of ingenious men, fertile in reſources, and acquainted with the variety and extent of the ſcience which they cultivated. A ſyſtem of knowledge, which is thus aſſimilated to the genius of the people, that is diffuſed ſo widely among them, and diverſified ſo much, has a right to be regarded, either as a native, or a very ancient inhabitant of the country where it is found.

IV. THE conſtruction of theſe tables implies a great knowledge of geometry, arithmetic, and even of the theoretical part of aſtronomy.

IN proof of this, it is unneceſſary to recapitulate the remarks that have been already made. It may be proper, however, to add, that the method of calculating eclipſes, to which theſe tables are ſubſervient, is, in no reſpect, an empirical one, founded on the mere obſervation of the intervals at which eclipſes return, one after another, in the ſame order. It is indeed remarkable, that we find no trace here of the period of 6585 days and 8 hours, or 223 lunations, the *Saros* of the Chaldean aſtronomers, which they employed for the prediction of eclipſes, and which (obſerved with more or leſs accuracy) the firſt aſtronomers every where muſt have employed, before they were able to analyſe eclipſes, and to find out the laws of every cauſe contributing to them. That empirical method, if it once exiſted in India, is now forgotten, and has long ſince given place to the more ſcientific and accurate one, which offers a complete analyſis of the phenomena, and calculates, one by one, the motions of the ſun, of the moon, and of the node.

BUT what, without doubt, is to be accounted the greateſt refinement in this ſyſtem, is the hypotheſis employed in calculating the equations of the centre for the ſun, moon and planets, that, *viz.* of a circular orbit having a double eccentricity,

or

or having its centre in the middle, between the earth and the point about which the angular motion is uniform *. If to this we add the great extent of geometrical knowledge requiſite to combine

* It ſhould have been remarked before, that M. Bailly has taken notice of the analogy between the Indian method of calculating the places of the planets, and Ptolemy's hypotheſis of the equant, though on different principles from thoſe that have been followed here, and ſuch as do not lead to the ſame concluſion. In treating of the queſtion, whether the ſun or earth has been ſuppoſed the centre of the planetary motions by the authors of this aſtronomy, he ſays, " Ils ſemblent avoir reconnu que les " deux inégalités (l'équation du centre et la parallaxe de l'orbe annuel) etoient vues de " deux centres differens ; et dans l'impoſſibilité où ils étoient de déterminer et le lieu et " la diſtance des deux centres, ils ont imaginé de rapporter les deux inégalités à un point " qui tînt le milieu, c'eſt-à-dire, à un point également éloigné du ſoleil, et de la terre. " Ce nouveau centre reſemble aſſez au centre de l'équant de Ptolemee. (Aſt. Ind. Diſc. Prel. p. 69.) The fictitious centre, which M. Bailly compares with the equant of Ptolemy, is therefore a point which biſects the diſtance between the ſun and earth, and which, in ſome reſpects, is quite different from that equant; the fictitious centre, which, in the preceding remarks, is compared with the equant of Ptolemy, is a point of which the diſtance from the earth is biſected by the centre of the orbit, preciſely as in the caſe of that equant. M. Bailly draws his concluſion from the uſe made of half the equation *ſchigram*, as well as half the equation *manda*, in order to find the argument of this laſt equation. The concluſion here is eſtabliſhed, by abſtracting altogether from the former, and conſidering the caſes of oppoſitions and conjunctions, when the latter equation only takes place. If, however, the hypotheſis of the equant ſhall be found of importance in the explanation of the Indian aſtronomy, it muſt be allowed that it was firſt ſuggeſted by M. Bailly, though in a ſenſe very different from what it is underſtood in here, and from what it was underſtood in by Ptolemy.

For what farther relates to the parts of the aſtronomy of Chaldea and of Greece, which may be ſuppoſed borrowed from that of India, I muſt refer to the 10th Chap. of the *Aſtronomie Indienne*, where that ſubject is treated with great learning and ingenuity. After all, the ſilence of the ancients with reſpect to the Indian aſtronomy, is not eaſily accounted for. The firſt mention that is made of it, is by the Arabian writers ; and M. Bailly quotes a very ſingular paſſage, where Massoudi, an author of the 12th century, ſays, that Brama compoſed a book, entitled, *Sind-Hind*, that is, *Of the Age of Ages*, from which was compoſed the book *Magbiſti*, and from thence the *Almageſt* of Ptolemy. Aſt. Ind. Diſc. prel. p. 175.

The fabulous air of this paſſage is, in ſome meaſure, removed, by comparing it with one from Abulfaragius, who ſays, that, under the celebrated Al Maimon, the 7th Khalif of Babylon, (about the year 813 of our era) the aſtronomer Habash compoſed three ſets of aſtronomical tables, one of which was *ad regulas Sind Hind ;* that is, as Mr Costard explains it, according to the rules of ſome Indian treatiſe of aſtronomy. (Aſiatic Miſcel. Vol. I. p. 34.) The *Sind-Hind* is therefore the name of an aſtronomical book that exiſted in India in the time of Habash, and the ſame, no doubt, which Massoudi ſays was aſcribed to Brama.

combine this, and the other principles of their aſtronomy together, and to deduce from them the juſt concluſions; the poſſeſſion of a calculus equivalent to trigonometry; and, laſtly, their approximation to the quadrature of the circle, we ſhall be aſtoniſhed at the magnitude of that body of ſcience, which muſt have enlightened the inhabitants of India in ſome remote age, and which, whatever it may have communicated to the weſtern nations, appears to have received nothing from them.

Such are the concluſions that ſeem to me to follow, with the higheſt probability, from the facts which have been ſtated. They are, without doubt, extraordinary; and have no other claim to our belief, except that, as I think has been fully proved, their being falſe were much more wonderful than their being true. There are but few things, however, of which the contrary is impoſſible. It muſt be remembered, that the whole evidence on this ſubject is not yet before the public, and that the repoſitaries of Benares may contain what is to confirm or to invalidate theſe obſervations.

FINIS.